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Missing E_T in Jets Due to Leakages into Scintillator Barrel Calorimeter

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Missing E_T arising from fluctuations of the tails of the high P_T jets in the Scintillator Barrel Calorimeter (SB) if the latter is not instrumented is compared with natural missing E_T background from neutrino. Using the GEANT parameterization of hadronic showers in SB it is shown that non-instrumented SB will generate a background to the missing E_T measurements up to a few TeV. Though this background is about one order of magnitude below the natural "irreducible" background from neutrino its contribution might become important. An attempt to reduce the neutrino background using associated leptons produces in the same event is discussed.

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Introduction.

Missing E_T physics is one of the significant issues of the GEM physics program [1]. Many new particles – supersymmeric particles (gluino, neutralino etc.), t-quark and new exotic particles – have missing E_T signatures and can be found in this channel during the 1-st year of operation of SSC[2]. To have high discovery potential for the new physics GEM detector should be capable to measure missing E_T energy correctly above 100 GeV [1] .

In this paper we are trying to estimate the importance of the measurements in the Scintillator Barrel Calorimeter for the missing E_T physics. GEM

Scintillator Barrel Calorimeter is located in a barrel region $|\eta| \leq 1.28$ after 6 λ of Liquid Ionization Electromagnetic and Hadron calorimeters [3]. Jets in the barrel region have high p_T and some part of the hadronic energy of the jet can fluctuates into SB that will results in the missing E_T signal in case of non-instrumented SB. Often the longitudinal segmentation in the liquid calorimeter sections and scintillator barrel layers might help to estimate the amount of energy leaked out into SB section. But if SB section is not instrumented some fluctuations, as for example one shown in Fig.1 can not be compensated. To estimate the contribution of such a fluctuations following steps were undertaken:

- Because the fluctuations of hadronic showers into SB is the source of missing E_T we need genuine reproduction of these fluctuations in MC simulations. To use GEANT for real jets seems to be very time consuming procedure. We choose more realistic scheme by parametrizing the probability of the energy deposition in the SB for different hadron energies and depths (through full GEANT simulation of individual hadrons) and found a simple logarithmic law of energy dependence extrapolation.

- Jets produced by $PYTHIA5.6$ event generator in different p_T bins are used with the above hadron parametrization to pick up randomly the energy deposition in SB. To improve statistics each event generated by $PYTHIA$ independently went through fluctuation procedure 100 times.

- Missing E_T spectrum induced by SB is compared with Standard Model missing E_T background which is produced by cascade quark decays. These decays are often accompanied by lepton pairs $(e, \nu_e), (\mu, \nu_\mu), (\tau, \nu_\tau)$ with neutrino carrying out significant part of missing energy.

- Standard Model background (from cascade quark decays) can be reduced by applying different cuts. One can try to do that using associated leptons produces in the same event pointing in the direction close to the missing E_T vector - this cut will reduce the Standard Model background but will not significantly suppress the background induced by SB.

Parametrization of hadron energy fluctuations in Scintillator Barrel Calorimeter

Hadrons (π^- of different energies 1,4,10,40,100 and 500 GeV were generated using $GEANT$3.15 in the GEM geometry around 90°. Energy deposition were recordered and analized in the SB calorimeter by steps of 0.33 λ to take into account the different thickness of absorber before SB at different angles. The spectrum of hadrons of different energies in SB is shown on Fig.2. One can see some events (at the level of 10^{-3}) with $E_{dep} > 0.5E_{tot}$ energy deposition in SB. These numbers seem to be natural if one estimates the probability for hadron to go through 6 λ of absorber without nuclear interactions ($e^{-6} \approx 0.3$ %). It is important to notice that though the average energy deposition by individual hadron in SB is only at a level of few per cent, fluctuations of this energy can go beyond 50%. By going from 6 λ to 7 λ in the liquid barrel, the energy deposition spectrum of SB changes according to simple exponential expectations (see Fig.3). The parameterization of the data is made in form of two histograms: 10 bins 0.0-0.1 of E_{dep}/E_{tot} and 10 bins 0.-1. of E_{dep}/E_{tot} (Fig.4a, 4b). Parametrized fluctuation spectrum is cross checked with one produced by direct GEANT simulation in Fig.5. This parameterization is used to describe the hadron fluctuations in SB.

Standard Model missing E_T background and comparison with missing E_T spectrum induced by non-instrumented Scintillator Calorimeter

10^5 SSC event were generated using PYTHIA5.6 in different P_T bins: 1-30, 30-80, 80-150, 150-300, 300-500, 500-800, 800-1000, 1000-2000, 2000-3000, 3000-5000, 5000-10000, 10000-20000 GeV. Standard Model neutrino background can easily be taken from this PYTHIA events by multiplying each individual missing E_T spectrum by corresponding cross-section.

To simulate missing E_T background arising from non-instrumented SB, the same events were used with hadronic parameterization described above (each PYTHIA event was treated 100 times to improve statistics). Only hadrons with $|\eta| < 1.2$ went through parametrization procedure, other particles were assumed being perfectly detected in the full unlimited acceptance. The absorbtion length of absorber in Liquid Calorimeter modules for this

region was chosen to be constant and equal 6λ independent of η. This assumption is nearly corresponds to the actual GEM design[3] in the region $\eta = 0.0 - 0.8$ and overestimates the leakages in the region $\eta = 0.8 - 1.2$. The comparison of two spectrum - missing E_T arising from non-instrumented SB and Standard Model ν-background – is presented in Fig.6. From this figure one can see that the missing E_T spectrum from SB is about one order of magnitude below one from the neutrino background. It has a tail which extends to TeV region. This seems to be a natural feature of the missing E_T spectrum from SB, because its origin is high p_T hadrons (with $|\eta| < 1.2$), and the inclusive spectrum of such hadrons continues to TeV region (Fig. 7). The effect of limited calorimeter coverage (leakages into region $|\eta| > 5$) is presented on fig.8 compared to the effect from SB and neutrino. One can see that the effect of limited calorimeter coverage dominates over neutrino background for $E_T < 100GeV$ (This conclusion was first made in [4]), and that the missing E_T from SB dominates over the calorimeter coverage for $E_T > 150GeV$. From these figures one can calculate the number of missing E_T events due to the non-instrumented SB (number of events is normalized to $L = 10^{34}$):

$E_T^{miss} > 100.$ GeV ≈ 140 pb $\equiv 1.4 \times 10^7$ events/SSC year

$E_T^{miss} > 200.$ GeV ≈ 6 pb $\equiv 0.6 \times 10^6$ events/SSC year

$E_T^{miss} > 500.$ GeV ≈ 0.3 pb $\equiv 0.3 \times 10^5$ events/SSC year

Summarizing the points mentioned above one notices that in non-instrumented Scintillator Barrel Calorimeter significant missing E_T signal will be produced by high energy leading hadrons which has little or no interactions in liquid EM and HC and whose cross-section at SSC is more than one order of magnitude above the cross-section of Standard Model missing E_T background from neutrino. The tail of this distribution continues to TeV region.

Possible reduction of Standard Model background

Neutrino produced in cascade quark decays is a natural background for the missing E_T physics. Because of the weak nature of these decays they are often accompanied by the (l, ν_l) pairs. Such leptons will go very often in the direction of the missing E_T vector, because quark masses are relatively low (except t-quark) compared to the missing E_T physics scale. On fig.9 the distribution of the angle $\Delta\phi$ between the missing E_T vector (including the

region $|\eta| > 5$)[1] and the most energetic muon in the same event is shown. Only muons with $P_T > 20$ GeV in the region $|\eta_\mu| < 2.5$ were considered. Note that it is possible to measure only 2 components of the missing E_T vector and our selection procedure includes only information about ϕ direction of vectors. One can see that about 50% of neutrino background can be rejected by requiring energetic muon $P_T > 20GeV$ measured in the muon chambers with $\Delta\phi < 6°$ to the direction of the missing E_T vector. About the same rejection factor could be reached by tagging other leptons – e and τ – but this seems to be more difficult to do because these leptons are accompanied by hadrons from the same jet. Using only μ-cut the rejection factor of 2 can be obtained (Fig.10). This factor is close to the possible limit for eliminating the W-Standard Model backgrounds ($W \to e\nu_e$, $W \to l\nu_l$), because about 50 % of the SM background goes from $Z_0 \to \nu\nu$ [2]. Fig.11 summarizes the non-instrumented Scintillator Calorimeter missing E_T background versus the μ-corrected SM background which is still order of magnitude higher.

Conclusion.

Scintillator Barrel Calorimeter, in case of no measurements of the energy deposition there, will produce pseudo-missing E_T events up to 1 TeV and will generate $E_T^{miss} > 100GeV$ trigger of about 1.4 Hz at 10^{34} luminosity. Corresponded events are generated by high energy leading hadrons in a jet and hardly can be corrected by weighting of Liquid Calorimeters sections. Cross-section of such events is though one order of magnitude below the Standard Model E_T^{miss} spectrum from neutrino. The neutrino background can be reduced by factor 2 by requiring to have no energetic muon ($P_T > 20GeV$) in the ϕ cone less than 6° around the E_T^{miss} vector. It will be reduced more by using different cuts based on the specific event topology (f.e. the requirement of isolation lepton for t-quark and high jet multiplicity for gluino [2]). This cuts can reduce the Standard Model background and the one from Scint.Calorimeter by different factor (μ-cut proposed above is an example) and hence will increase the significance of the measurements in the Scintillator Barrel Calorimeter.

[1](As it was shown in [4] jets produce at $|\eta| > 5$ will not contribute to the missing E_T spectrum significantly for $E_T^{miss} > 100$ GeV)

Acknowledgements

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References

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[2] *Large Hadron Collider Workshop, Proceedings Vol.II,* Aachen, 4-9 October 1990.

[3] GEM Collaboration, *Progress Report on the GEM Detector Baseline Design,* GEM TN 92-231 (1992).

[4] F.E.Paige and A.V.Vanyashin, *Effects of Limited Calorimeter Coverage on* E_T^{miss}, GEM TN-92-70 (1992).

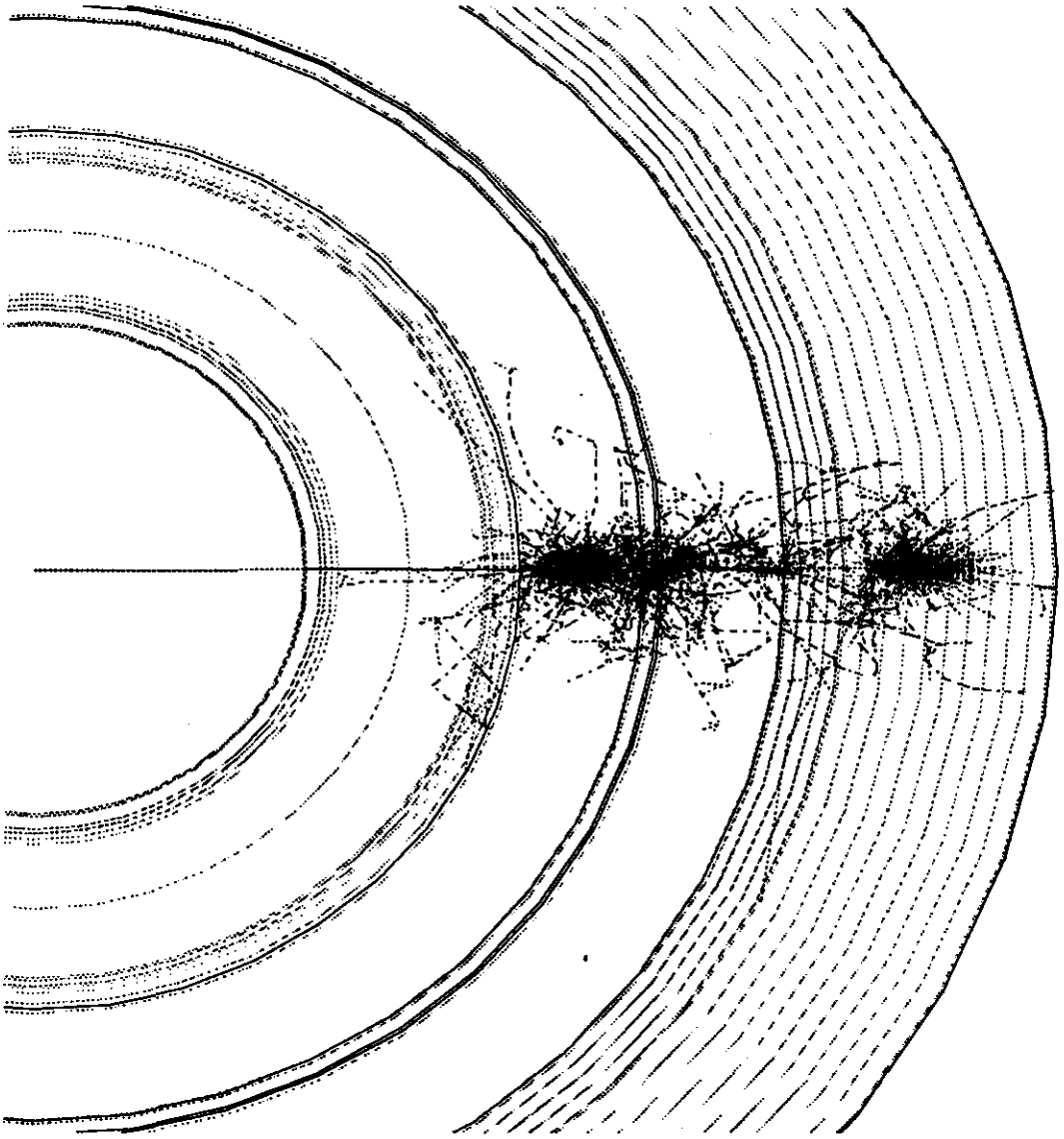

Fig. 1

100 GeV π^- shower at 90°. An example of the hadron event with high energy deposition in SB. 2 sections of EM Pb/LKr calorimeter, interface to HC modules, 2 modules of HC, support and cryostat walls and SB from inside to outside) are shown.

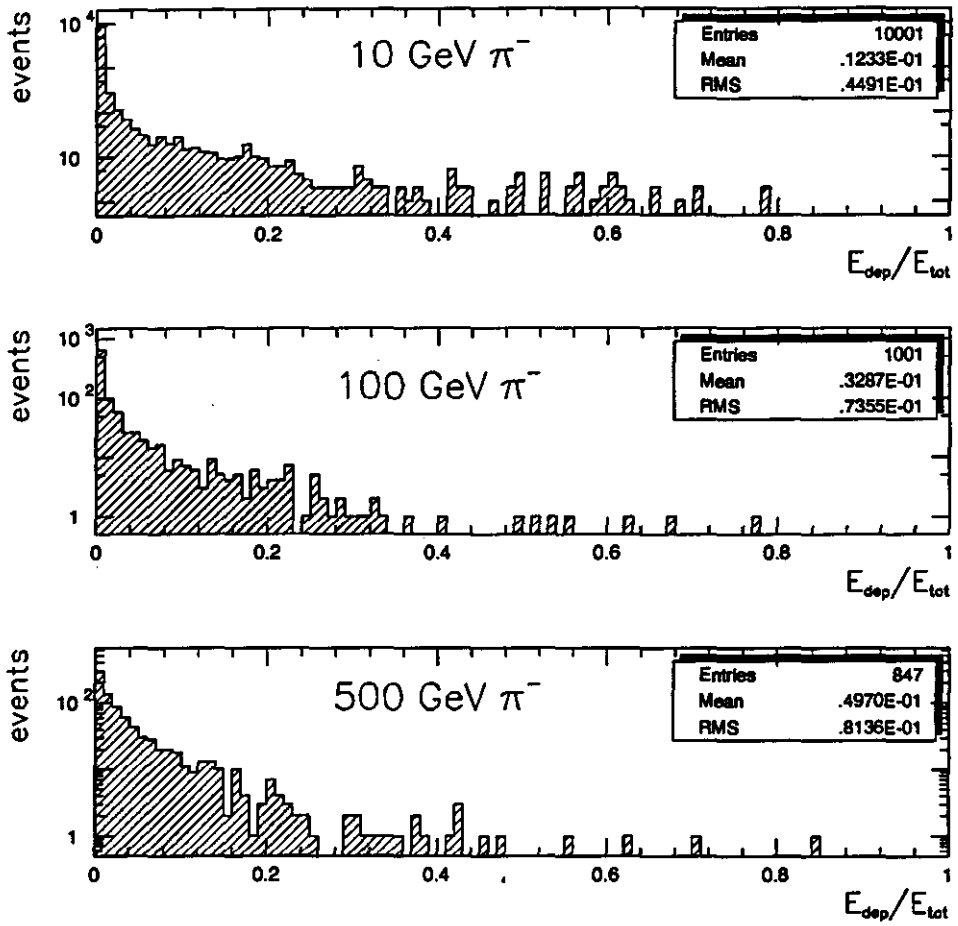

Fig. 2

Spectrums of 10,100 and 500 GeV π^- in Scintillator Barrel Calorimeter at 90° after 6λ of Liquid Calorimeters. The average energy deposition in Scint.Cal. is 1.2 % at 10 GeV, 3.3 % at 100 GeV and 5.0 % at 500 GeV. One can see events with more than 300 GeV deposition in SB at 500 GeV.

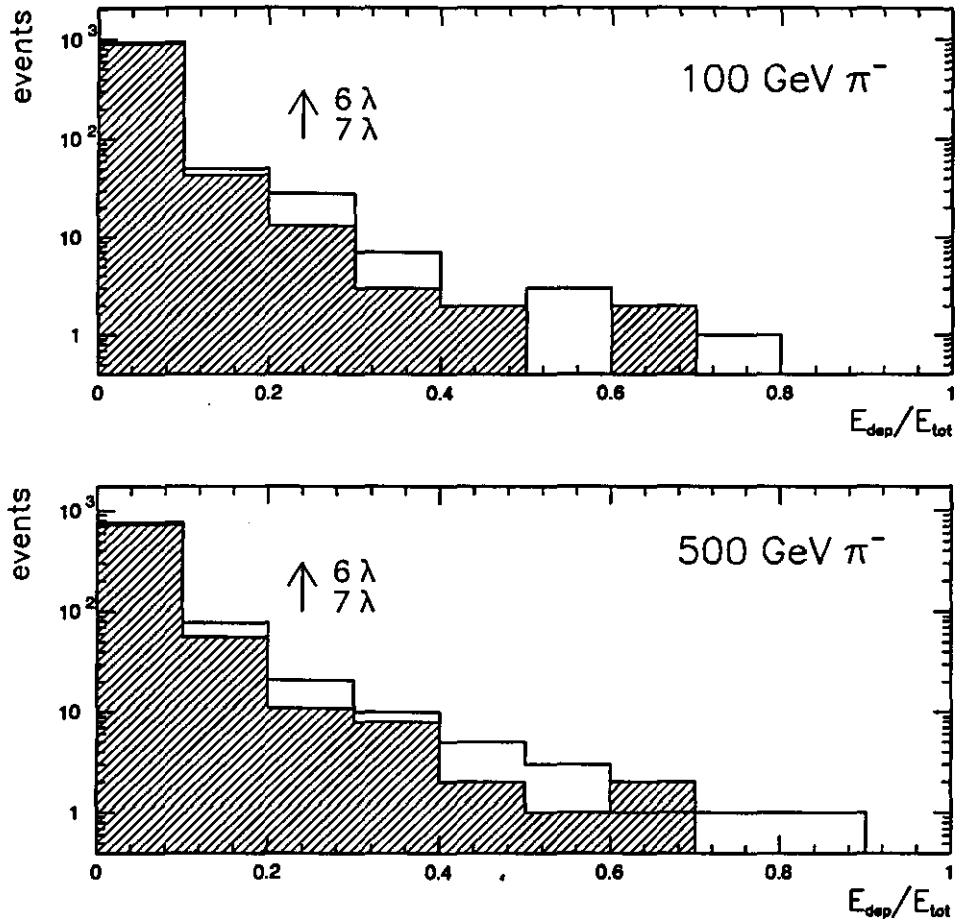

Fig. 3

Spectrums of 100 and 500 GeV hadrons in Scintillator Barrel Calorimeter after 6 and 7 λ of Liquid Calorimeters. One can see that ratio factor of about 2 exists for events at the tail part – close to the expected $\exp(-x/\lambda)$ *law.*

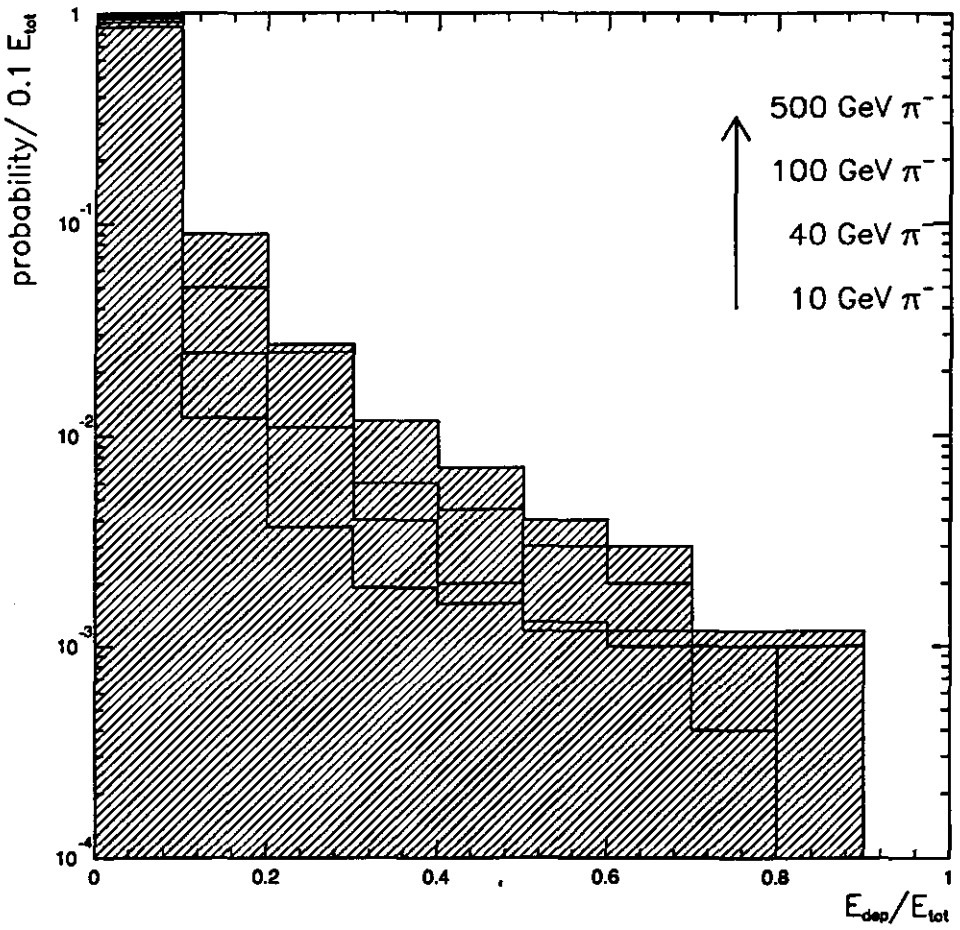

Fig. 4a

Parameterization of the hadron energy deposition in Scintillator Barrel Calorimeter at 90° (6 λ). Probability is plotted in bins of $0.1E_{tot}$ *as a function of the ratio* E_{dep}/E_{tot} *– fraction of the total energy deposited in Scint.Cal., (0.-1.)*E_{tot} *scale. One can see that histograms looks similar and differs by factor 2-3 at the tail part for energies 10-500 GeV.*

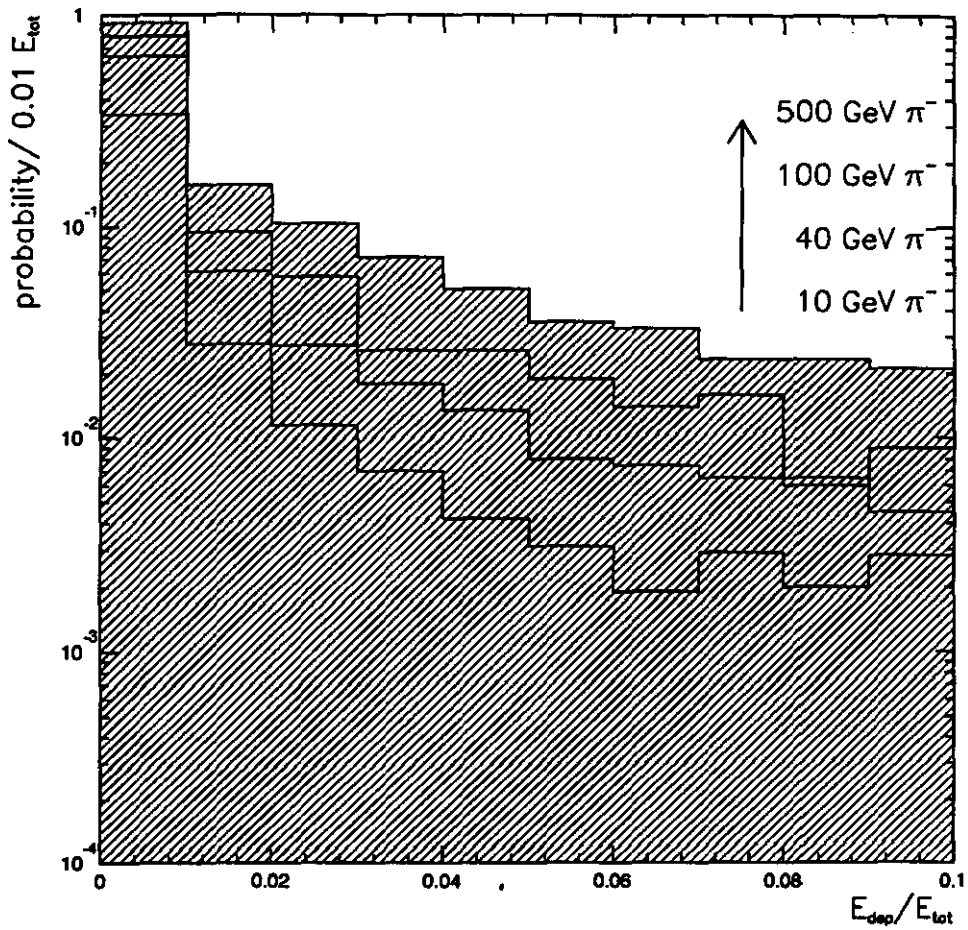

Fig. 4b

Parameterization of the hadron energy deposition in Scintillator Barrel Calorimeter at 90° (6 λ). Probability is plotted in bins of $0.01E_{tot}$ *as a function of the ratio* E_{dep}/E_{tot} *– fraction of the total energy deposited in Scint.Cal., (0.0-0.1)*E_{tot} *scale. One can see the probability ratio of about factor 10 at the tail between 10 GeV and 500 GeV.*

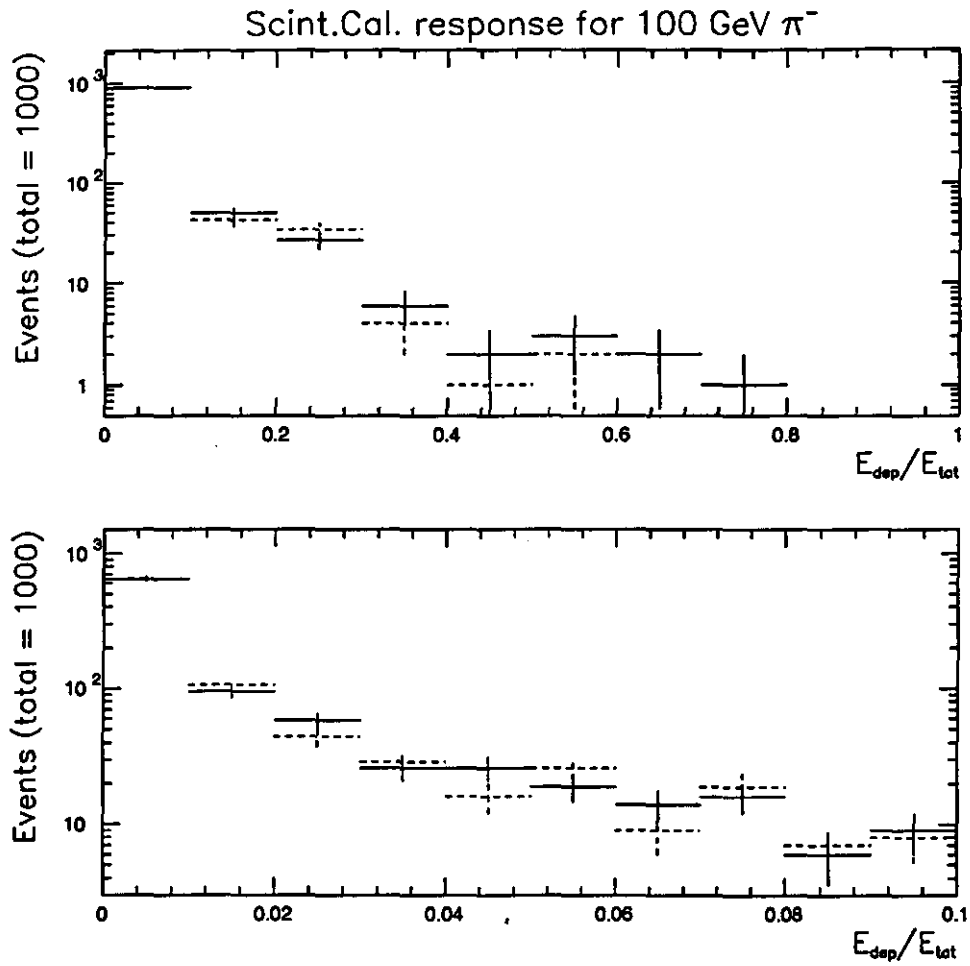

Fig. 5

Fraction of energy deposited in SB section of calorimeter. Parameterization versus GEANT full Monte-Carlo for 100 GeV π^- in two scales a) 0.-1. E_{tot}, b) 0.0-0.1 E_{tot}. Solid points - GEANT 3.15, dashed points - parameterization. Total number of events - 1000.

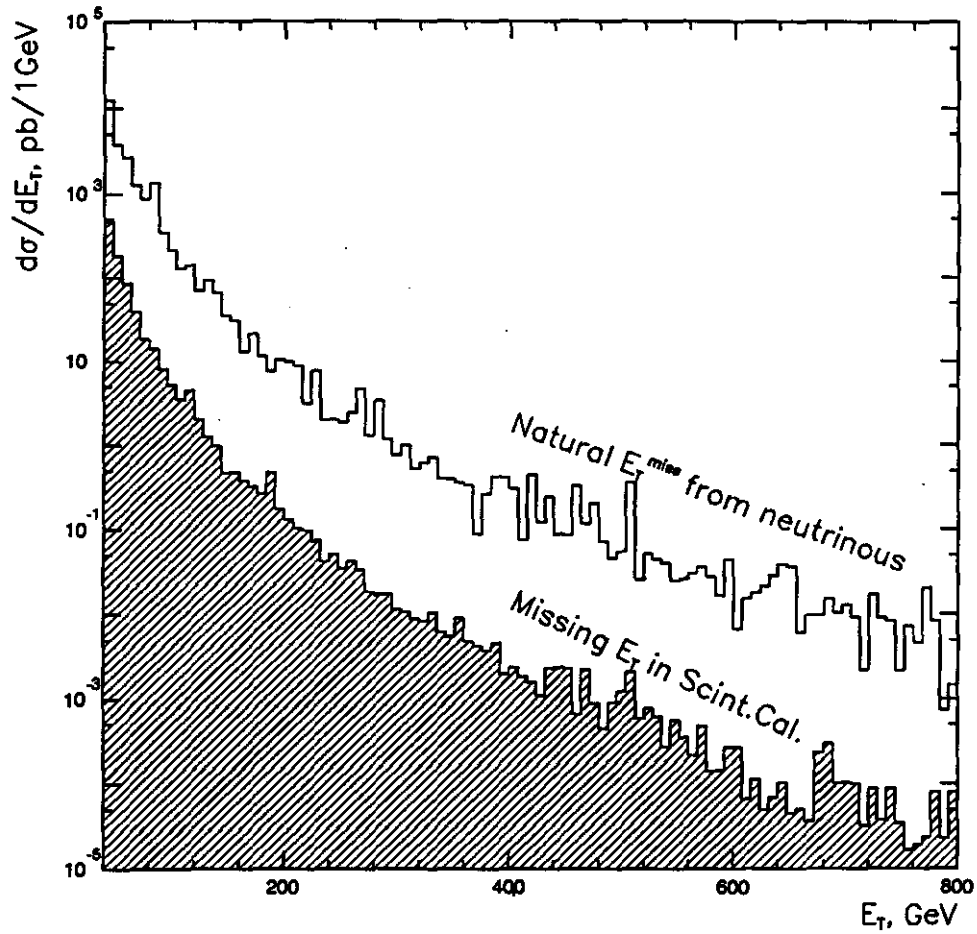

Fig. 6

Natural E_T^{miss} spectrum from neutrino (Standard Model Background) and E_T^{miss} spectrum originated in Scint.Cal. (if it is not instrumented). This plots were generated as a sum of 12 distributions of 100,000 PYTHIA events with different p_T^q with corresponding cross-sections.

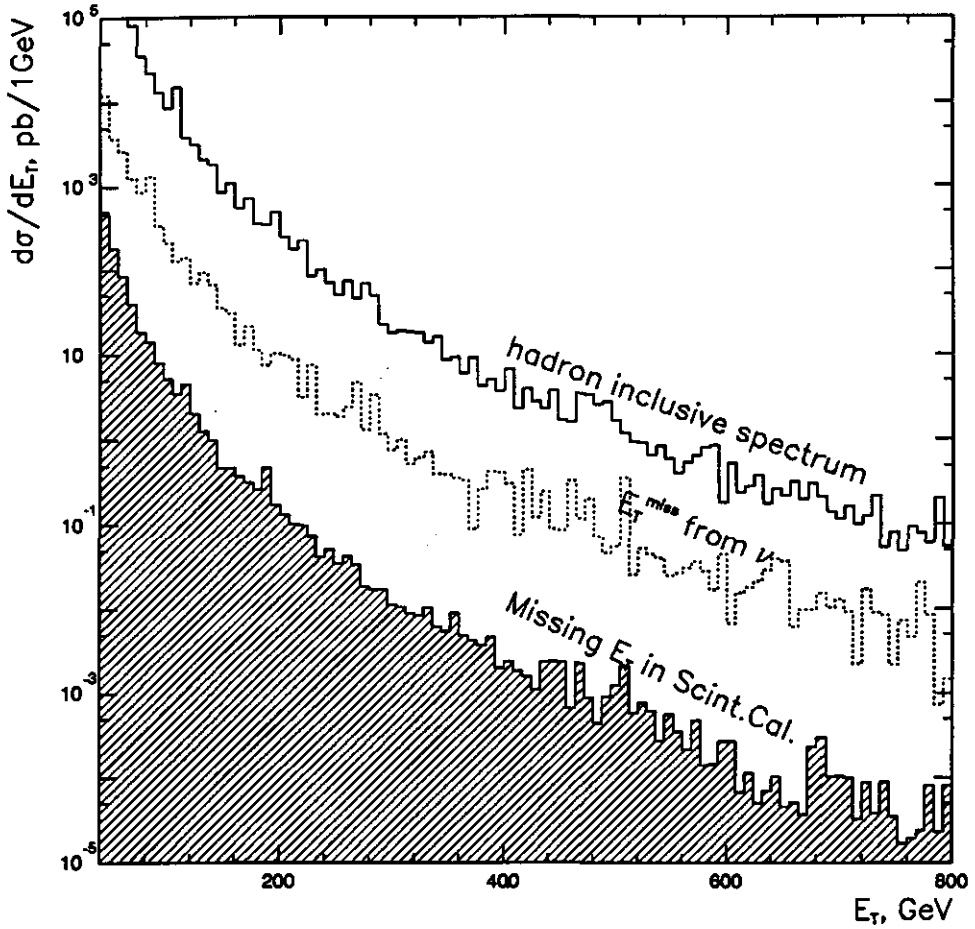

Fig. 7

E_T^{miss} spectrum originated in Scint.Cal. compared to hadron inclusive cross-section from jets $|\eta| < 1.2$. Also it is shown (dotted line) E_T^{miss} Standard Model background.

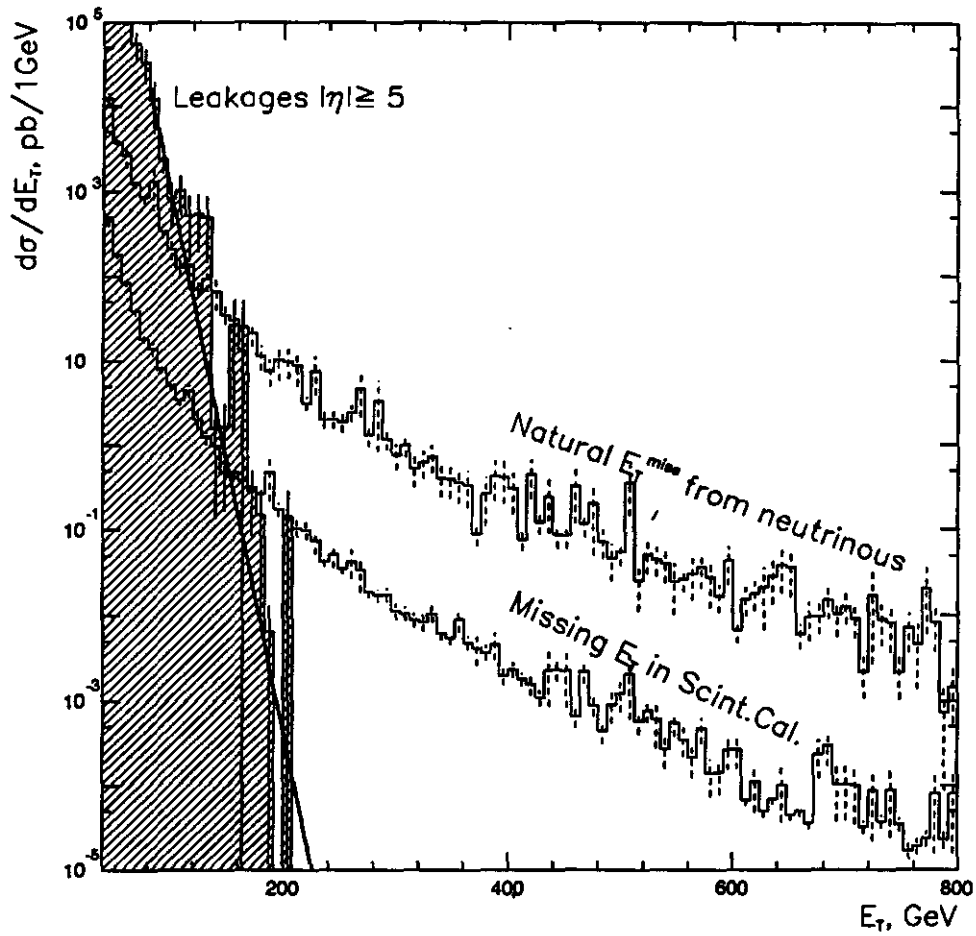

Fig. 8

The effect of limited calorimeter coverage $|\eta| < 5$ versus E_T^{miss} spectrum from neutrino (Standard Model background) and E_T^{miss} spectrum originated in Scint.Cal. in case if it is not instrumented.

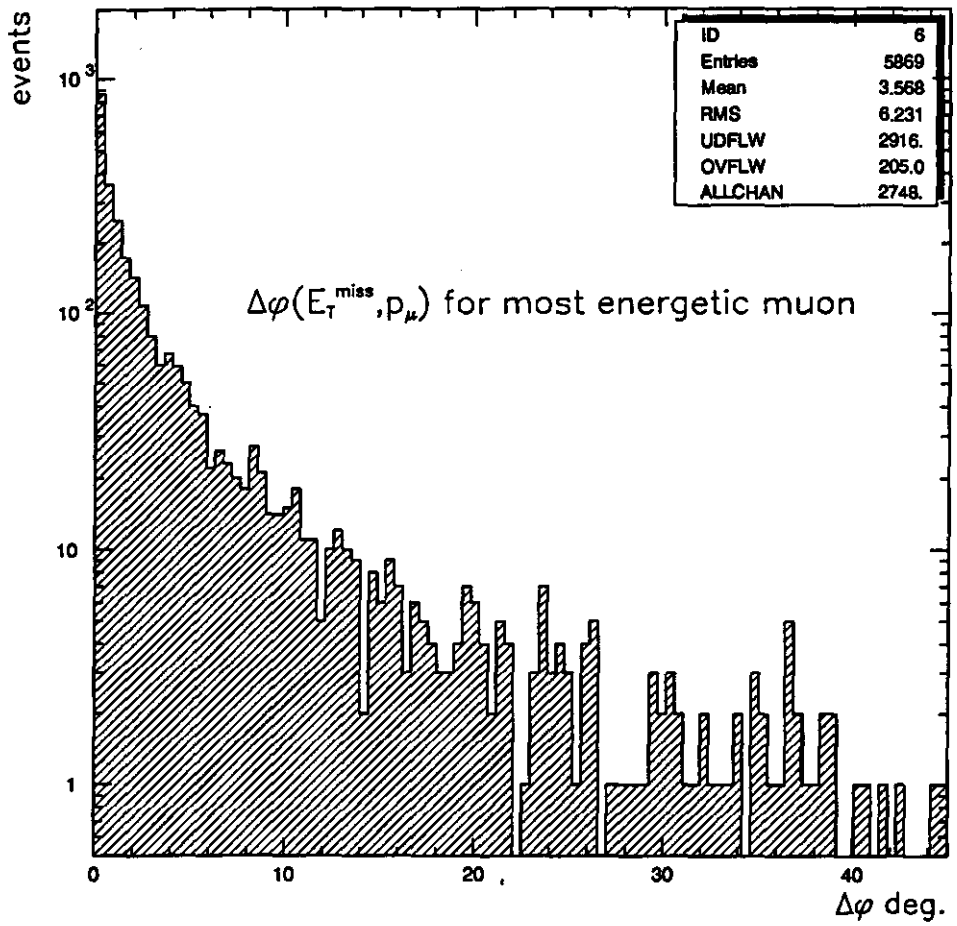

Fig. 9

The angle $\Delta\phi$ between missing E_T vector and the most energetic muon in the event. E_T^{miss} includes leakages into region $|\eta| > 5$. Only events with $E_T^{miss} > 20GeV$ and $p_T^{\mu} > 20$ GeV in the region $|\eta_\mu| < 2.5$ are included in the analysis.

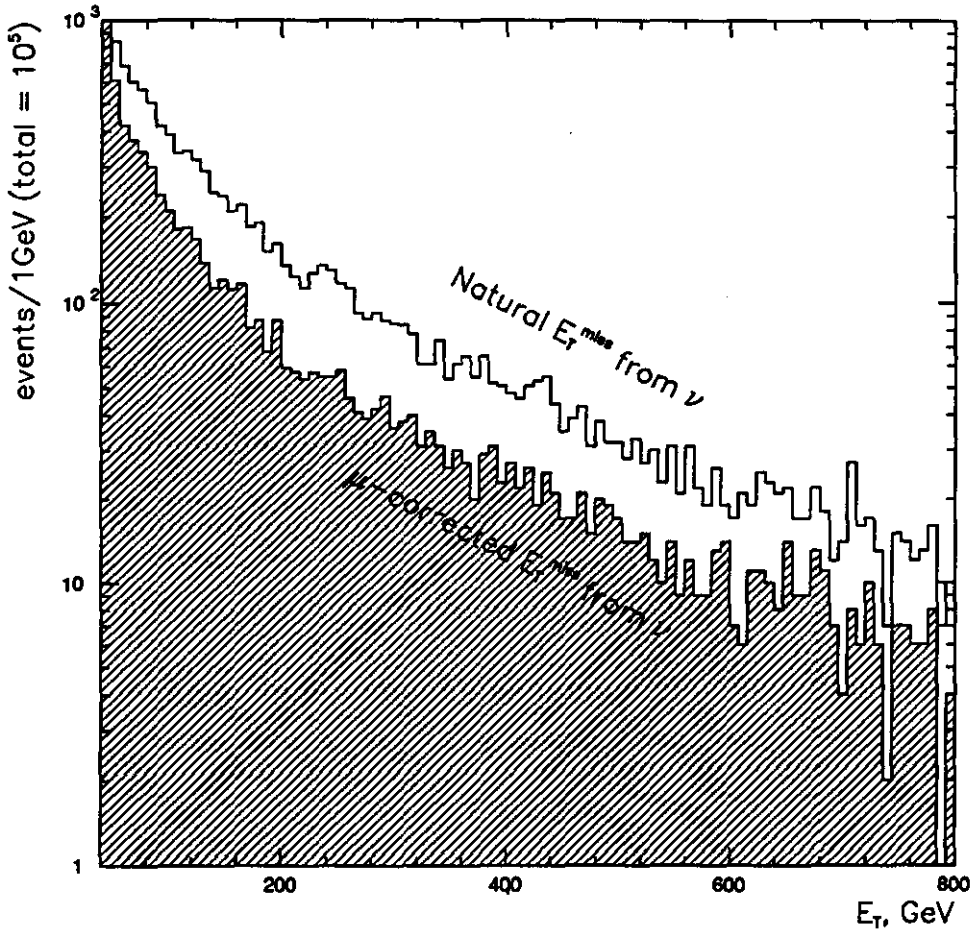

Fig. 10

Correction of natural E_T^{miss} spectrum from neutrino by μ-cut — no muons $p_T > 20$ GeV in the region $|\eta_\mu| < 2.5$ with $\Delta\phi(p_\mu, E_T^{miss}) < 0.1$. This plot is for PYTHIA events generated with 2 TeV $< p_T^q <$ 3 TeV.

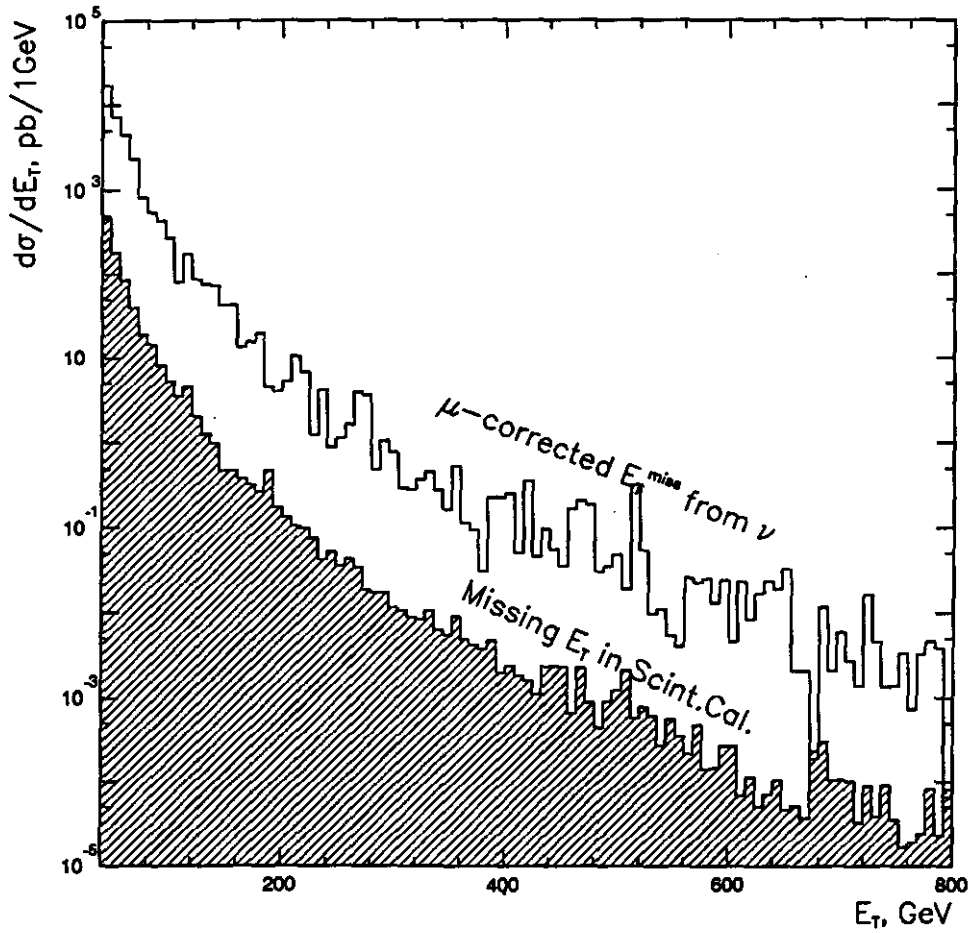

Fig. 11

Standard Model E_T^{miss} background after μ-cut and E_T^{miss} spectrum originated in Barrel Scint.Cal.