Observation of Anomalous Dimuon Events in the NuTeV Decay Detector (Preliminary)

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A search for long-lived neutral particles (N^0) which decay into at least one muon has been performed using an instrumented decay channel at the E815 (NuTeV) experiment at Fermilab. The decay channel was composed of helium bags interspersed with drift chambers, and was used in conjunction with the NuTeV neutrino detector to search for N^0 decays. The data were examined for particles decaying into the muonic final states $\mu\mu$, μe, and $\mu\pi$. Three $\mu\mu$ events were observed over an expected background of 0.040 ± 0.009 events; no events were observed in the other modes. Although the observed events share some characteristics with neutrino interactions, the observed rate is a factor of 75 greater than expected. No Standard Model process appears to be consistent with this observation.

I. INTRODUCTION

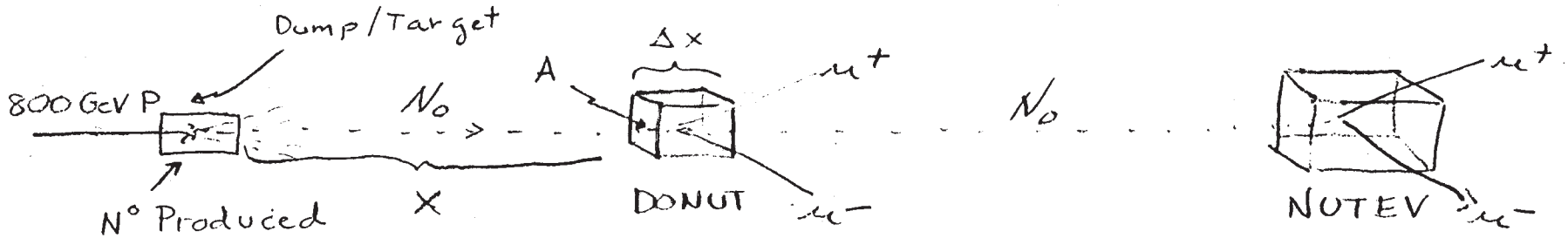
In various extensions to the Standard Model, new particles exist which have reduced couplings to normal quarks and leptons. These new particles may have zero electric charge, long lifetimes, and small interaction rates with normal matter. We shall refer to these as N^0 particles in the following text. Examples of such N^0 particles include neutral heavy leptons (NHLs) or heavy sterile neutrinos [1–3] and neutral supersymmetric particles [4] such as neutralinos and sneutrinos. The N^0 particles can be produced either by pair production in hadronic interactions or via weak decays of mesons through mixing with standard neutrinos. The decays of the N^0 to normal hadrons and/or leptons can proceed through weak decays with mixing, or via R-parity violating supersymmetric processes.

High energy neutrino beamlines are ideal places to produce N^0 particles, since very large numbers of protons interact in these beamlines. N^0's may be produced via a number of mechanisms, including primary interactions of the protons either in the target or the beam dump, through prompt decays of charmed or bottom mesons, by decays of pions or kaons in the decay region, or in neutrino interactions in the shielding downstream of the decay region. A particle detector placed downstream of this sort of beamline (i.e., in the neutrino beam itself) can be used to search for N^0 decays.

We report here the results of a search using Fermilab's E815 (NuTeV) detector for N^0 particles in the mass region above 2.2 GeV/c^2 which decay into final states with at least one muon and one other charged particle. For the search described here, the NuTeV neutrino beamline was used in conjunction with a low mass decay detector called the decay channel.

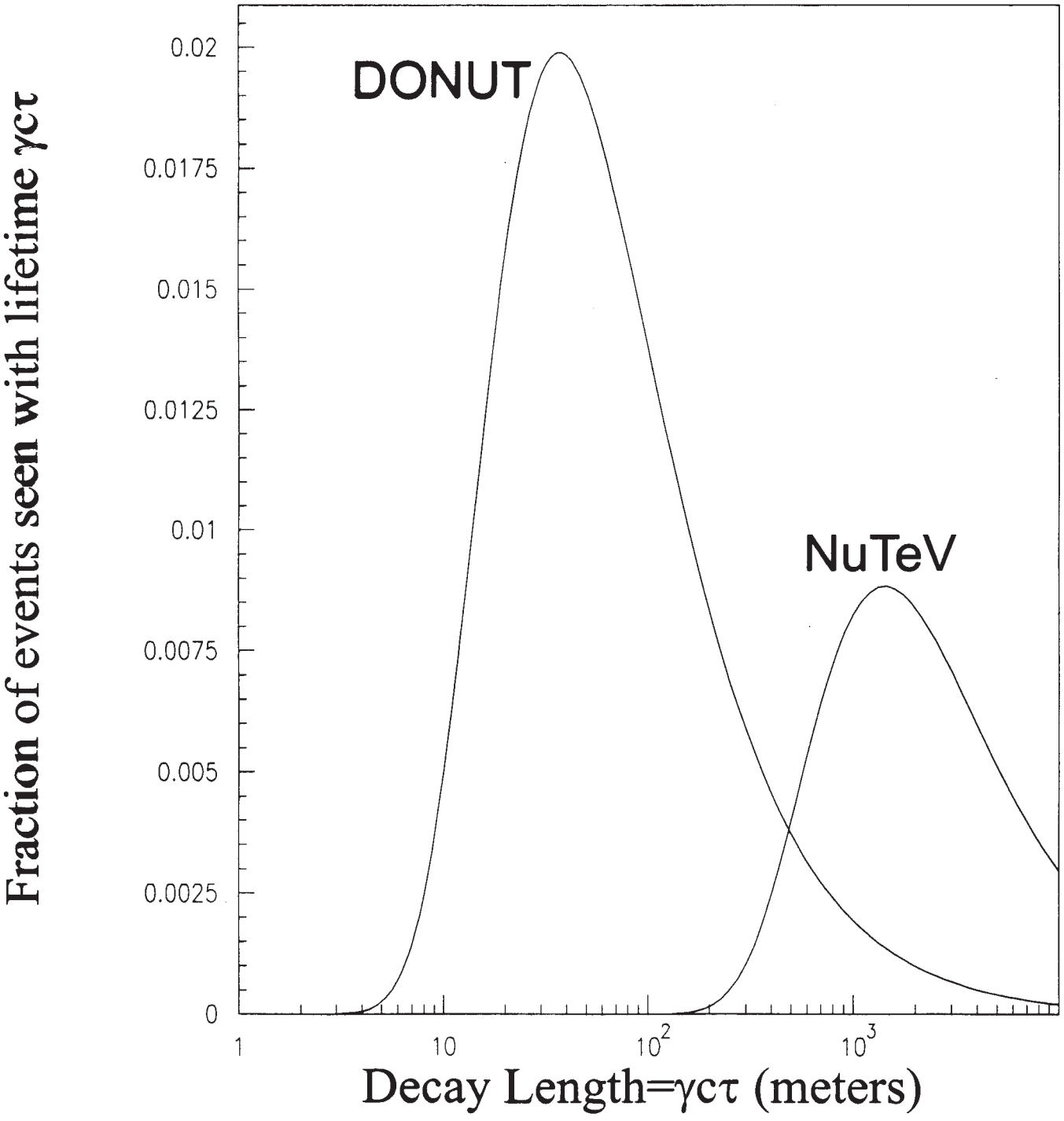
NuTeV has previously reported results of searches for N^0's in the mass region between 0.3 to 3.0 GeV/c^2 with at least one final state muon [5], and in the mass region below 0.3 GeV/c^2 for decays to electrons [6]. The 0.3 to 3.0 GeV/c^2 study addressed NHLs that could be produced in the decay of K and D mesons, whose hadronic production rate is known [7]. This mass region also has low background from deep inelastic neutrino events in the decay channel. The low mass (< 0.3 GeV/c^2) study was pursued mainly to address the KARMEN timing anomaly [8], which has been interpreted as a N^0 particle with a mass equal to 33.9 MeV/c^2.

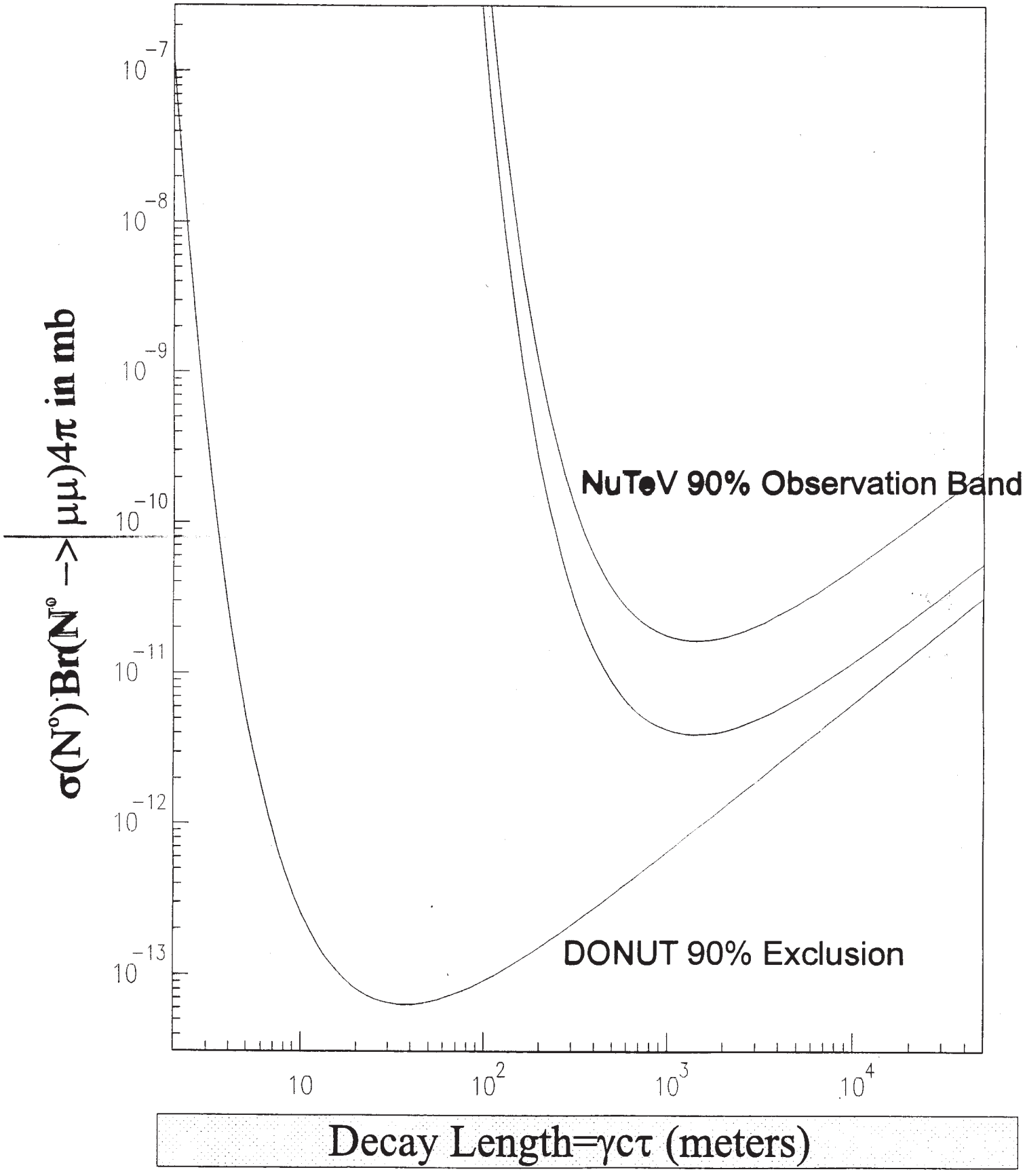
The search for events with masses above 2.2 GeV/c^2 (which we shall refer to as "the high mass region") is different from the previous searches in two respects. First,

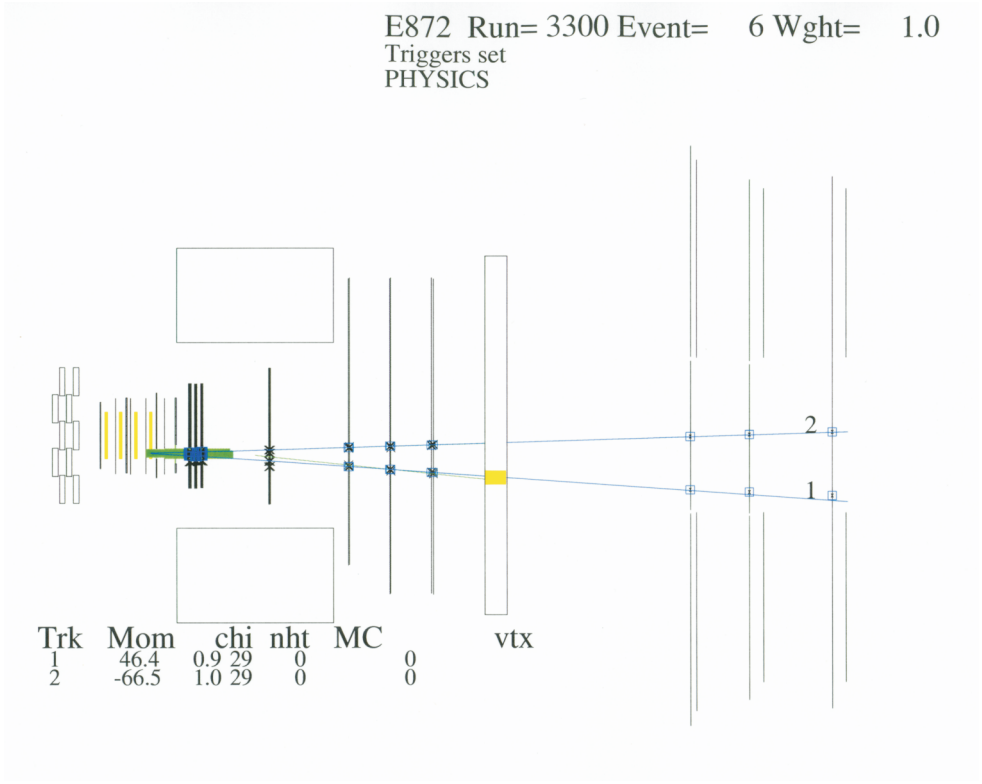


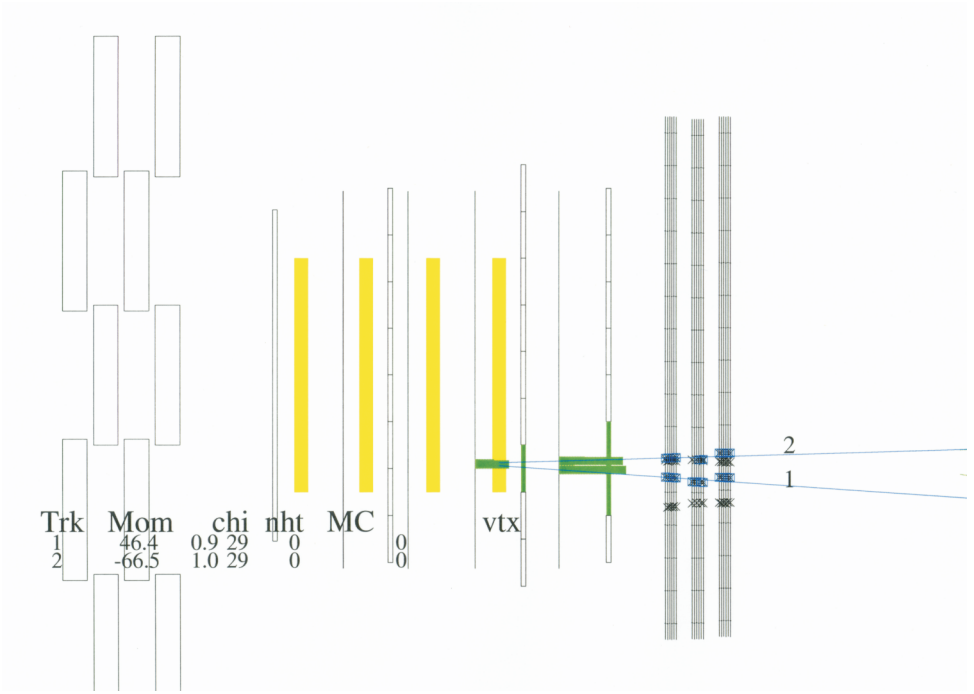
	DONUT	NuTeV
X	36 meters	1460 meters
Δx	~2 meters	34 meters
A	$\sim(0.5\,\text{meter})^2$	$(1.27\,\text{meter})^2$
POT	3.56×10^{17}	$2.54\times10^{18}\,(1-e^{-1})$

$$\frac{\text{DONUT}}{\text{NuTeV}} = 50\left(\frac{e^{-36\,\text{meters}/D\ell}\left(1-e^{-2\,\text{meters}/D\ell}\right)}{e^{-1400\,\text{meters}/D\ell}\left(1-e^{-34\,\text{meters}/D\ell}\right)}\right)$$

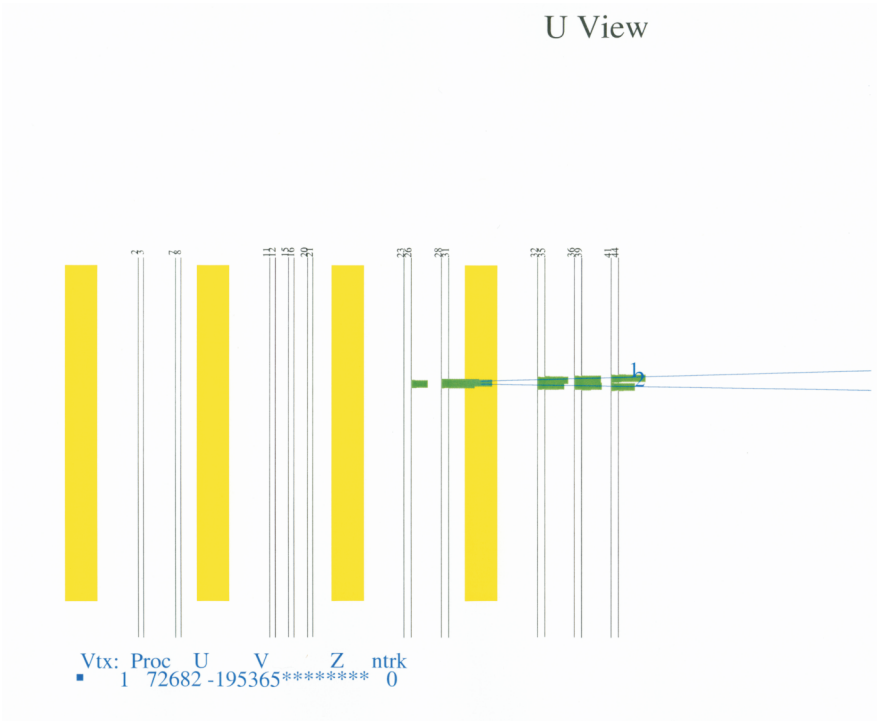

Fraction of events seen with lifetime γcτ
0.02
0.0175
0.015
0.0125
0.01
0.0075
0.005
0.0025
0
DONUT
NuTeV
1
10
10^2
10^3
Decay Length=γcτ (meters)


$\sigma(N^0)\cdot Br(N^0 \rightarrow \mu\mu)4\pi$ in mb
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
NuTeV 90% Observation Band
DONUT 90% Exclusion
10
10^2
10^3
10^4
Decay Length=γcτ (meters)

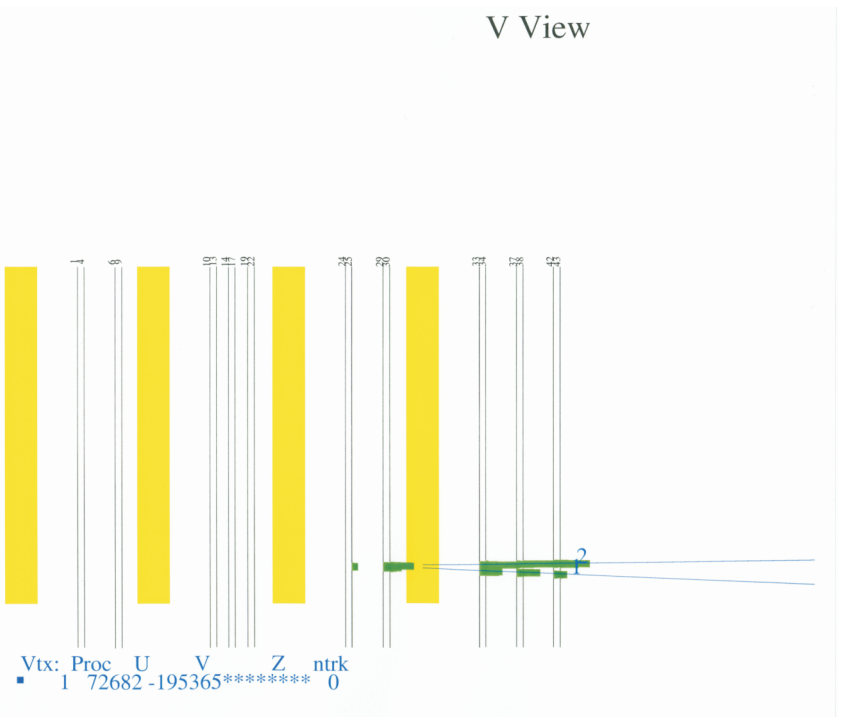

E872 Run= 3300 Event= 6 Wght= 1.0
Triggers set
PHYSICS
Trk Mom chi nht MC vtx
1 46.4 0.9 29 0 0
2 -66.5 1.0 29 0 0
2
1


Trk Mom chi nht MC vtx
1 46.4 0.9 29 0 0
2 -66.5 1.0 29 0 0
2
1

U View


Vtx: Proc U V Z ntrk
1 72682 -195365******** 0

V View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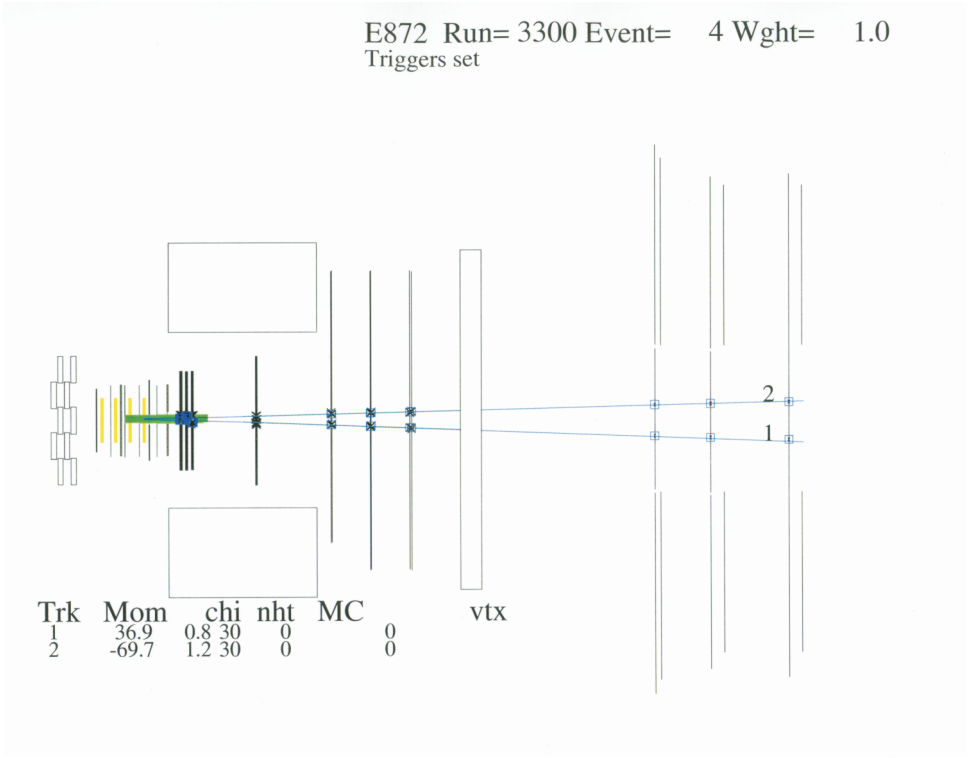
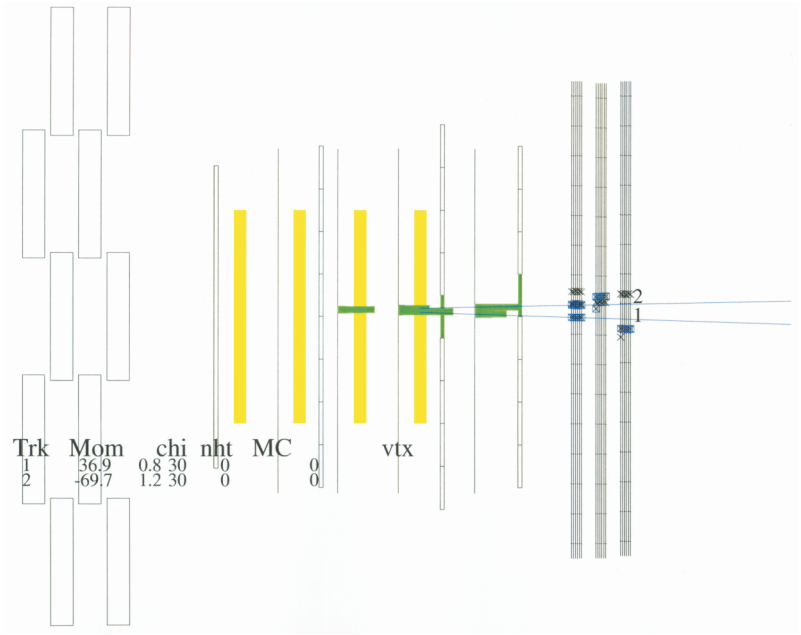
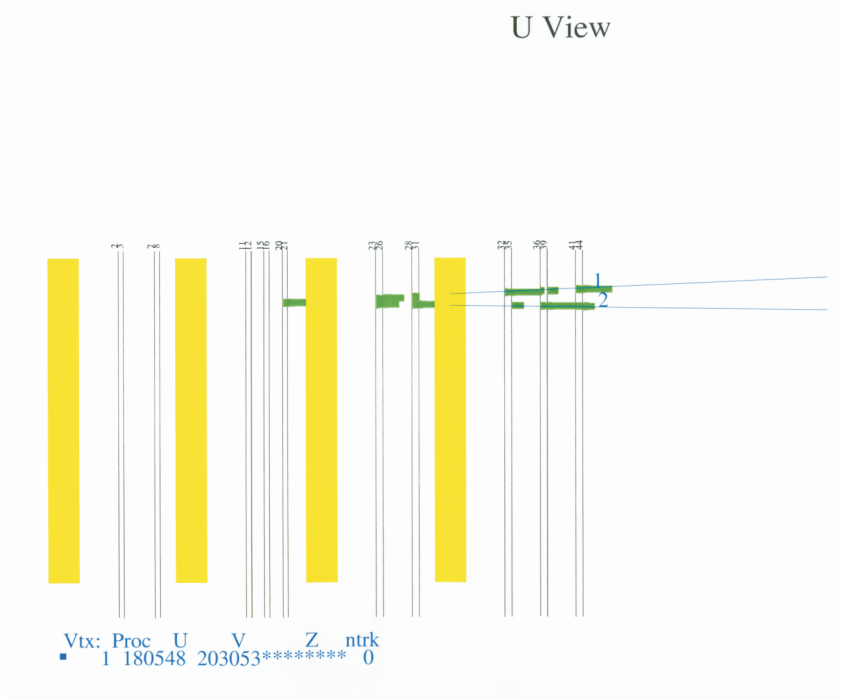
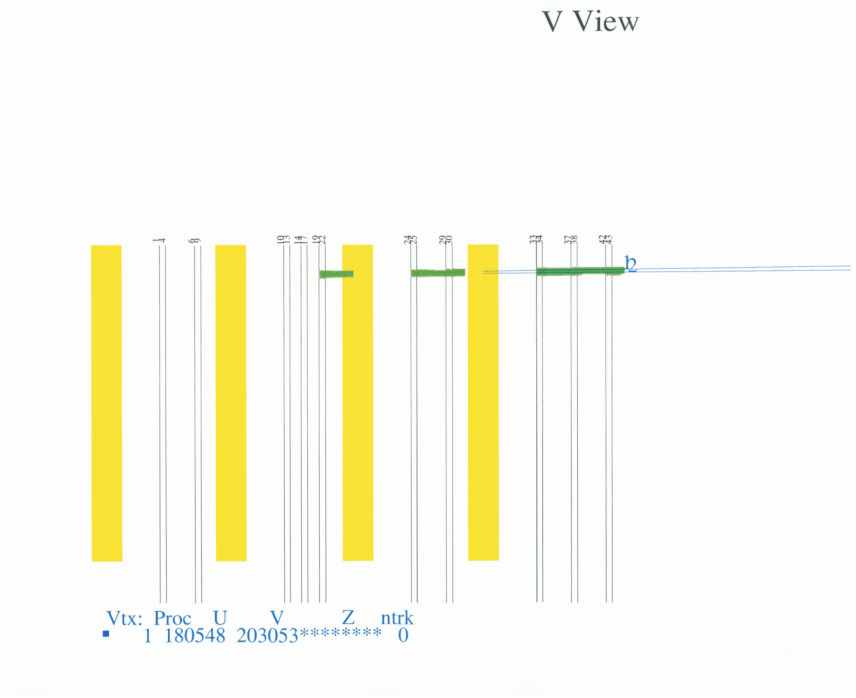
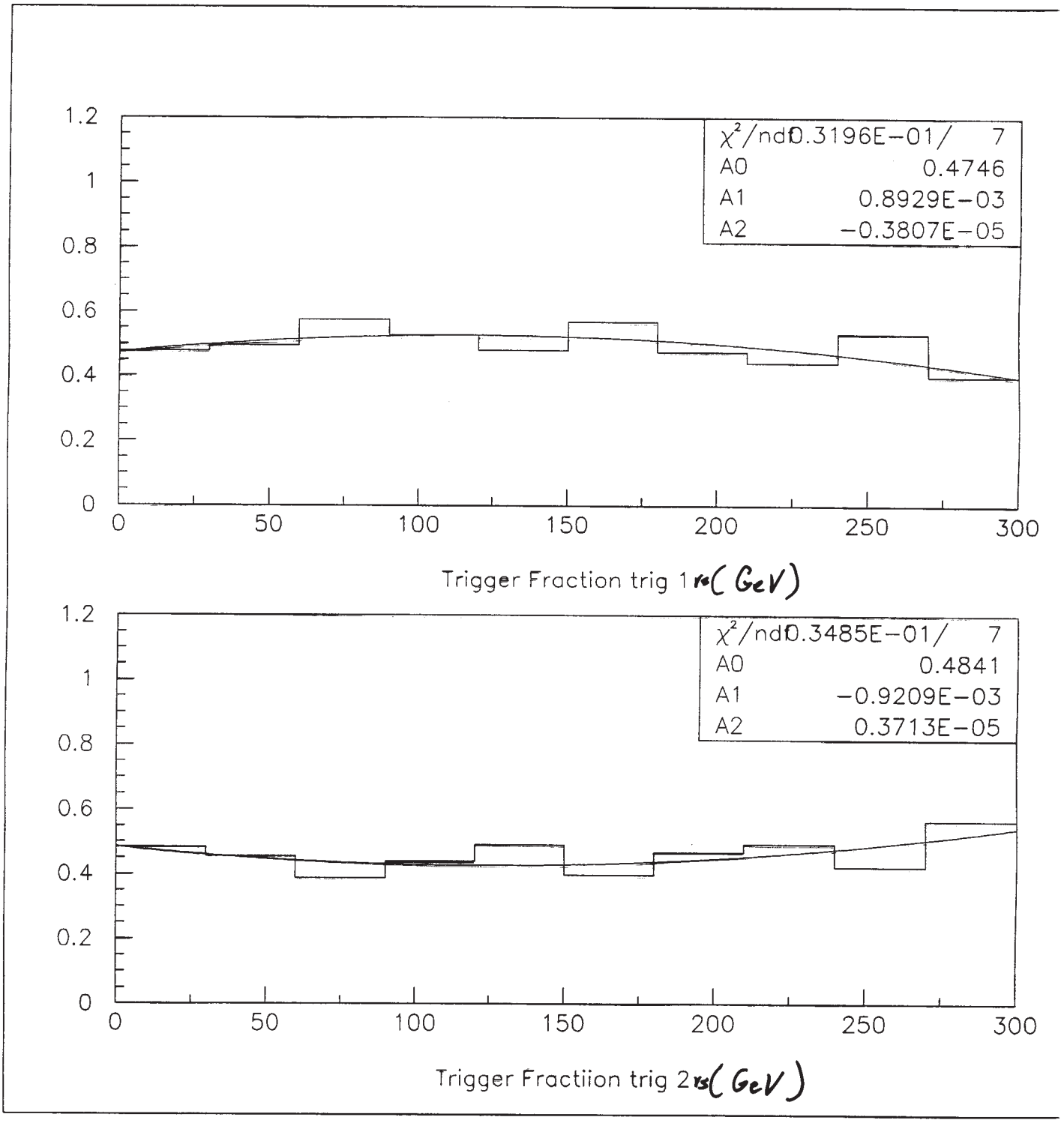

E872 Run= 3300 Event= 4 Wght= 1.0
Triggers set
2
1
Trk Mom chi nht MC vtx
1 36.9 0.8 30 0 0
2 -69.7 1.2 30 0 0

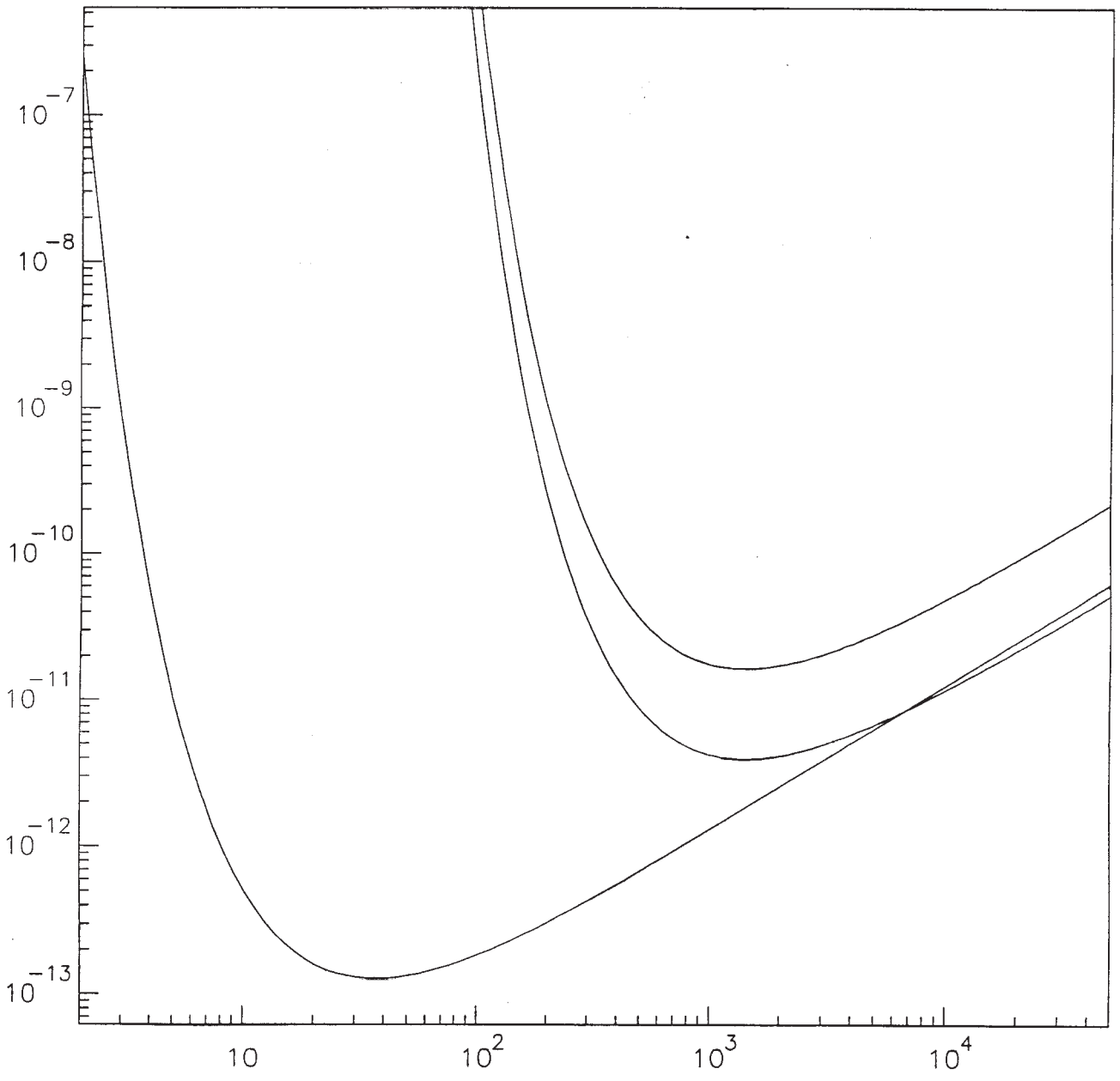

2
1
Trk Mom chi nht MC vtx
1 36.9 0.8 30 0 0
2 -69.7 1.2 30 0 0


U View
1
2
Vtx: Proc U V Z ntrk
1 180548 203053******** 0


V View
2
Vtx: Proc U V Z ntrk
1 180548 203053******** 0

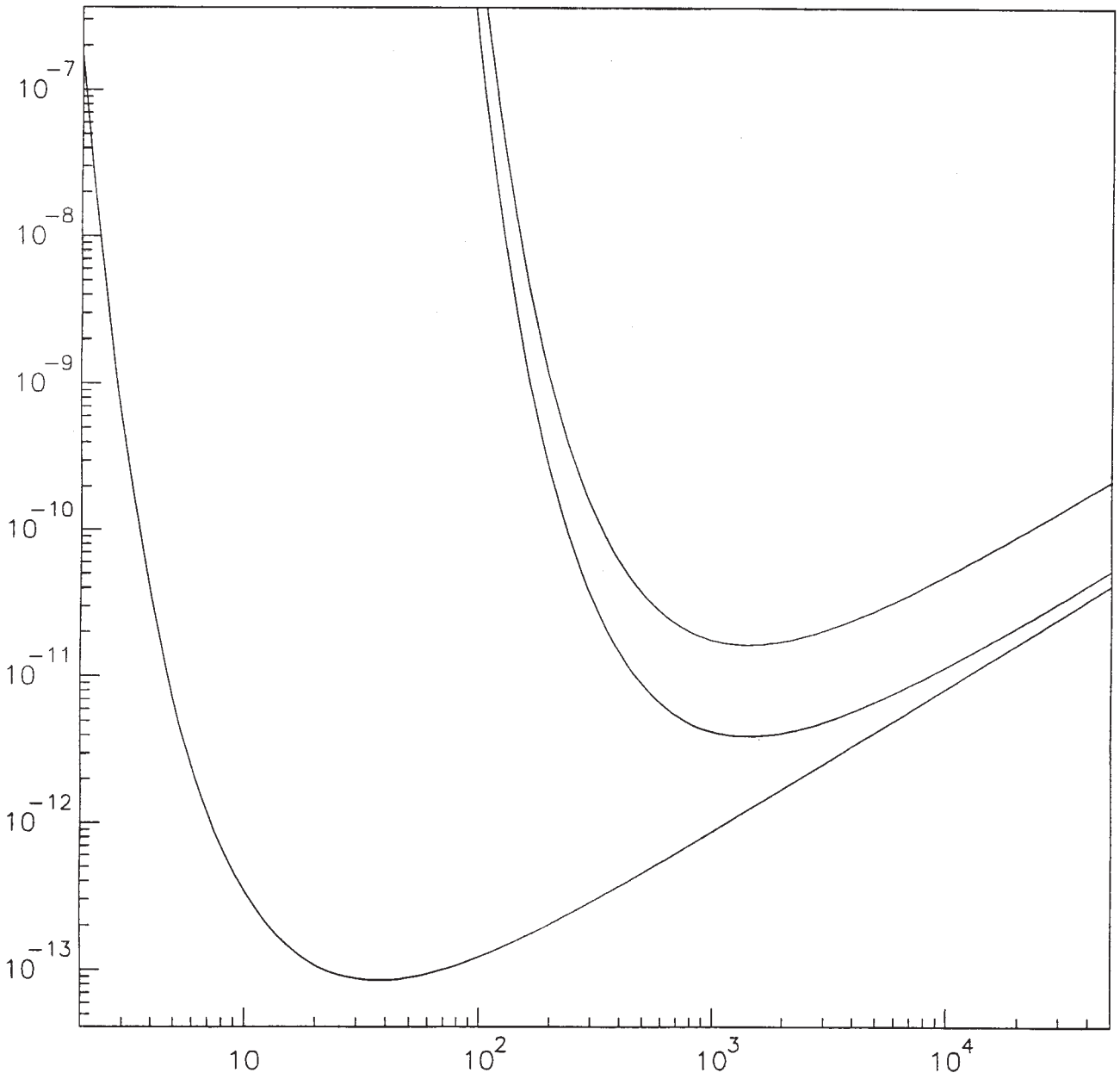

1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
χ²/nd 0.3196E-01 / 7
A0 0.4746
A1 0.8929E-03
A2 -0.3807E-05
Trigger Fraction trig 1 vs (GeV)
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
χ²/nd 0.3485E-01 / 7
A0 0.4841
A1 -0.9209E-03
A2 0.3713E-05
Trigger Fractiion trig 2 vs (GeV)

(periods) 1, 2, 3
Only trig 1
(2 track
min.)



2.0*(1./((exp(−36./x))*(1−exp(−2./x))))*((2.3*0.038)/(6.9*10000000000000.))

(trig 1 4 2
periods 1,2,3,4)



1.33*(1./((exp(−36./x))*(1−exp(−2./x))))*((2.3*0.038)/(6.9*10000000000000.))