NuTeV DET020

Progress Report on the NuTeV Decay Channel

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In Summer, 1996, an addition was made to the detector of the NuTeV Experiment (E815) at Fermi National Accelerator Laboratory to improve the NuTeV search for decays of exotic neutral leptons. This upgrade, called the "decay channel," was made to extend the physics of the experiment and has resulted in an improvement of the sensitivity to neutral heavy leptons of mass less than 2 GeV by over an order of magnitude in some regions, as shown in Figure 1. Data taking began in September, 1996, near the beginning of NuTeV and will continue through autumn, 1997. This report describes the progress of the NuTeV decay channel as of March, 1997.

1 Motivation and Method for the Search for Neutral Heavy Leptons

The search for neutral heavy leptons which undergo weak mixings with the Standard Model neutrinos has a long history.[1] Such relatively heavy neutrinos are not forbidden by the Standard Model and result from various plausible extensions to the theory.[2] In these extensions, the heavy neutrinos are isosinglets, but mix with the Standard Model neutrinos in such a way that the observed neutrinos have a small component of the heavy state. Simple models for the mixing have been developed and lifetimes and branching ratios for decays have been estimated.[2] A high statistics neutrino experiment with a multipurpose detector, such as NuTeV, is an ideal place to search for signs of the existence of these particles. NuTeV is more sensitive than previous experiments due to the high intensity, high energy neutrino beam and the large instrumented decay volume.

One possible source of neutral heavy leptons which could be observed by NuTeV is from particle production in the beam line. Mesons produced in the beam line can decay to a

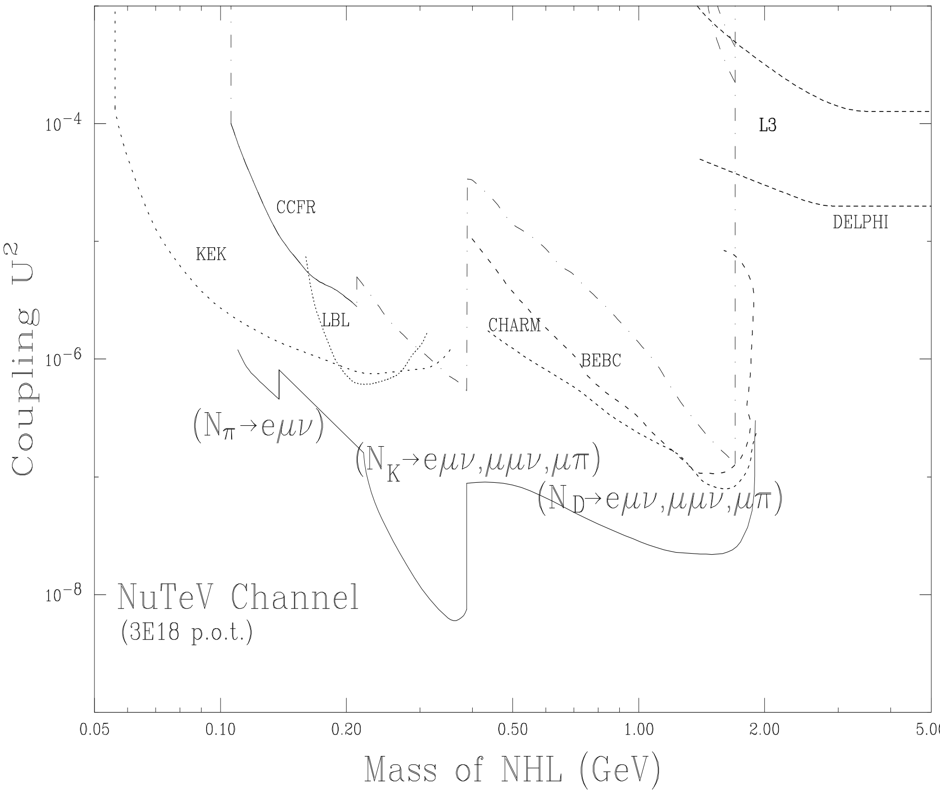

Figure 1: *Sensitivity of the NuTeV neutral heavy lepton search, for* 3×10^{18} *protons on target. Results from past experiments (see reference 1) are also shown*

neutral heavy lepton plus other particles. Examples of these meson decays are shown in Table 1. Because the beam line is 1.3 km, these neutral heavy leptons must have a relatively long lifetime and hence relatively low mass.

The neutral heavy leptons can decay through mixing with a light neutrino which radiates a W or Z boson. Examples of the Feynman diagrams for neutral heavy lepton decays are shown in Figure 2. The initial focus of this analysis will be searches for decays to muons: $N \rightarrow \nu\mu\mu, \nu\mu e$, and $\mu\pi$. In the future, we will extend this analysis to include $N \rightarrow \nu ee$ and $N \rightarrow e\pi$ decays. The former decay mode is particularly interesting for addressing the Karmen anomaly[3] which could be interpreted as a signal for a neutral heavy lepton with mass of 34 MeV.[4]

The expected sensitivity for the NuTeV decay channel for 3×10^{18} protons on target

$\pi^\pm \to Ne, N\mu$
$K^\pm \to Ne, N\mu, N\pi^0 e, N\pi^0\mu$
$K_L, K_S \to N\pi^\pm e^\mp, N\pi^\pm \mu^\mp$
$D^\pm \to Ne, N\mu, NKe, NK\mu$
$D^0 \to NKe, NK\mu$
$D_s^\pm \to Ne, N\mu, N\phi e, N\phi\mu, N\eta e, N\eta\mu$

Table 1: *Examples of meson decays producing neutral heavy leptons. The neutral heavy lepton is denoted by N above.*

(the expected NuTeV data sample), for decays to muons, is shown in Figure 1. The region of couplings and masses of the neutral heavy lepton which can be explored depend on the characteristics of the beam line, the decay channel and the particle identification detector. The region available to NuTeV is interesting to investigate because it extends into unexplored masses and mixings by over an order of magnitude.

The neutral heavy leptons within the NuTeV range of sensitivity may be the heavy isosinglet partner to the light neutrino that many other groups are pursuing.[5] In simple mixing models,[2] the mass of the neutral heavy lepton, light neutrino partner, and the mixing between these states are related. The new region of isosinglet masses and mixings which NuTeV can explore would correspond to light neutrino masses ranging from approximately 2 eV to 2 KeV. This mass range is consistent with: *a)* present bounds on light neutrino masses ($m_{\nu_\mu} < 170$ KeV)[6]; *b)* limits from cosmological models based on expansion rate ($m_\nu < 20 - 30$ eV)[7]; expectations from cosmological models using neutrino mass to explain the small scale structure of the universe and the recently measured anisotropy of the photon

Figure 2: *Two examples of Feynman diagrams for neutral heavy lepton decays. The NHL decays through mixing with the light neutrino partner. The decay probability*

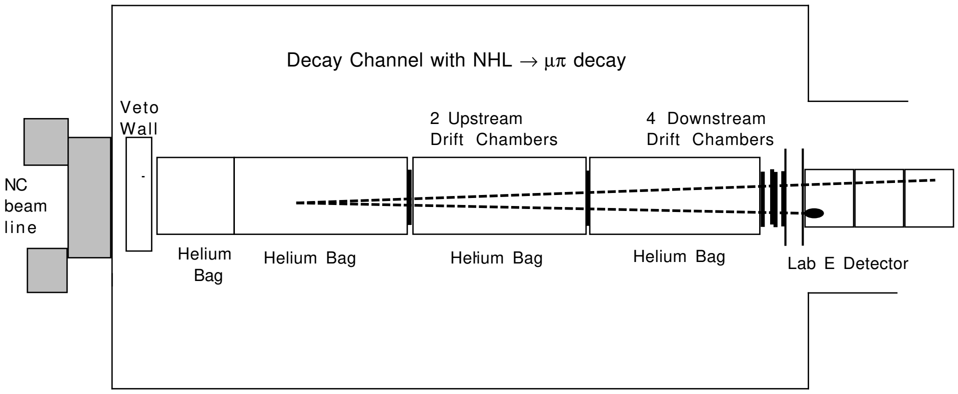

Figure 3: *Design of the NuTeV decay channel. An example of an NHL decay to $\mu\pi$ is shown in this schematic.*

background radiation[8]; and *c)* allowed regions for neutrino masses from the possible $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation signal reported by the LSND experiment at Los Alamos.[9]

In the following sections, the design and construction of the channel, the expected cuts to isolate events, and the backgrounds to the decay modes are considered in order to justify the expectation shown in Figure 1. These subjects were covered in extended detail in NuTeV memo DET019, so only a summary is presented here. Some information has been updated to reflect improvements in the decay channel design and results from the data sample collected from September 1996 to January 1997.

1.1 Configuration of the Decay Channel

The purpose of the decay channel is to observe decays of neutral heavy leptons to $\mu\mu\nu$, $\mu e\nu$ and $\mu\pi$. These neutral heavy leptons may be produced from meson decays in the NuTeV neutrino beam[10] and then traverse the neutrino beam line before reaching the decay channel. This section briefly describes the NuTeV neutrino beam line, the decay channel and the Lab E detector, which is currently taking data at Fermilab, as part of the 1996-97 Fixed Target Run.

The NuTeV neutrino beam results from decays of pions and kaons produced in interactions of the 800 GeV FNAL proton beam with a beryllium target. At the end of the Fermilab Fixed Target Run in September, 1997, the proton intensity associated with the decay channel running is expected to be 3×10^{18} protons on target. (This is approximately equal to the total intensity NuTeV will receive, because the decay channel was completed at the start of high intensity running of the neutrino line). Dipole magnets are used to select the sign of the charged pions and kaons and direct neutral kaons away from the detector. The resulting beam is almost purely ν_μ or $\overline{\nu}_\mu$, depending on the sign selection. The sign selection significantly reduces the systematics of the electroweak and some QCD analyses, but does not affect the systematics of the neutral heavy lepton analysis. The wide band beam produces a spectrum of neutrinos, and possibly neutral heavy leptons, with energies up to $\sim$400 GeV.

The decay channel consists of an instrumented decay volume located in Lab F at Fermilab. A hodoscope wall is positioned upstream to veto incoming charged particles. This is followed by a 40 m region in which the neutral heavy leptons can decay. Six drift chambers are installed for tracking of the charged decay products. The Lab E detector is used to identify the charged particles from the decays. In order to reduce backgrounds from neutrino events in the air between the decay channel chambers (discussed below), helium bags are installed. A diagram of the apparatus is shown in Figure 3. As an example, a neutral heavy lepton decay to a muon and pion is illustrated. The fiducial region of the decay channel, which includes cuts around the region of the chambers, is 35m long and 3m$\times$3m in the transverse dimension.

The veto consists of two hodoscope walls assembled mainly from 5ft $\times$ 5ft scintillation counters, covering a region 15ft $\times$ 15ft. The counters are assembled from new 2.5 cm Bicron BC-408 scintillator, installed in existing frames and using existing waveguides. The phototubes used on these counters were taken from NuTeV spares. Counter-by-counter coincidences between the two walls form the veto. The efficiency of this system has been measured to be 99%. The wall is installed at the upstream face of Lab F. Concrete blocks located outside of Lab F provide shielding from soft photons. This veto system has performed very well, and is now used as the veto for all physics triggers in the experiment (see section 3), since it substantially reduces the experiment's veto deadtime.

Spare NuTeV drift chambers were installed to provide the tracking for the decay channel. Each chamber has a 10ft$\times$10ft active area. The chambers are 13% of a radiation length. Six drift chambers are placed in the decay channel region, as shown in Figure 3. One chamber is tilted to allow three dimensional track reconstruction.

Helium bags are located in the regions between the upstream drift chambers. Replacing the air in the decay channel with helium reduces the rate of neutrino interactions within the decay channel fiducial volume by an order of magnitude. These interactions represent an important background, as discussed below.

The Lab E detector[11] provides particle identification. The detector consists of a target calorimeter with iron plates, scintillator and drift chambers and a toroid muon spectrometer with drift chambers and hodoscopes. Energy of muons can be determined by the range in iron or measurement in the toroid spectrometer. Energy of electrons and pions is determined by the target calorimetery. The specifics of the particle identification are discussed below. In general, muons are required to traverse approximately 2 m of steel, while electrons and pions are classified based on the shower profile. The NuTeV Test Beam provides samples of identified pions and electrons over a range of energies to permit tuning of the particle ID cuts.

1.2 Cuts to isolate the event sample

One must isolate neutral heavy lepton decays in the $\mu\mu\nu$, $\mu e\nu$ and $\mu\pi$ modes from backgrounds which can simulate these decays. In order to do this, a set of cuts which minimize the background must be determined. In this section, the cuts are described and the expected sources and magnitudes of backgrounds are summarized. An advantage of the $\mu\pi$ 2-body decay is that real events should cluster about a mass, making this mode less sensitive to a false signal from background.

In general the cuts are designed to identify an unaccompanied neutral particle which decays in the channel fiducial volume into only two charged particles which can be identified in the Lab E detector as two muons, a muon and an electron, or a muon and a pion. Studies used to determine these cuts were based on the data from the previous neutrino experiment (CCFR), the Lund Monte Carlo,[12] the Geant Monte Carlo,[13] and simulations of the detector and background events.[14−17] The cuts are summarized in Table 2.

For all candidate events, the requirements are: no hit in the Lab F veto wall, and only two tracks reconstructed in the Lab F drift chambers. These two tracks must come from a vertex which reconstructs within the decay channel volume, outside of the region of the chambers. The closest approach cut of less than 10 cm used in the initial study is unnecessarily large. In the future, we expect to reduce this to less than 1 cm, based on our present vertexing studies. This will reduce those sources of background with secondary decays somewhat further than is presented below. A 1% inefficiency in the veto wall was assumed for these studies, in good agreement with the measured inefficiency. The Monte Carlo studies below include smearing

General Cuts
No hits in veto wall
Only two tracks in Lab F drift chambers
Vertex reconstructed within the decay channel
Closest approach of tracks at vertex < 10 cm
Cuts which isolate $\mu e \nu$ and $\mu \pi$ events
One track extending through more than 2 m of steel
$E_{tot} > 10$ GeV
$\eta < 0.2, 0.3, 0.5$ for E_{tot} =10-20, 20-60, >60 GeV, respectively for $\mu e \nu$
$\eta > 0.2, 0.3, 0.5$ for E_{tot} =10-20, 20-60, >60 GeV, respectively for $\mu \pi$
Association of hits in Lab E detector with Lab F track
Cuts which isolate $\mu \mu \nu$ events
Two tracks extending through more than 2 m of steel
$E_{10\ ctrs} < 10$ GeV

Table 2: *Summary of cuts used in simulations to determine the NuTeV sensitivity shown in figure 1.*

of the hits for each track due to multiple scattering and the resolution of the chamber. The tracks were then reconstructed using a least-squares fit to the points.

In order to identify muons, tracks in the detector are required to extend beyond 2 m of steel (20 counters) into the Lab E detector. To isolate events with only two muons and no accompanying photons in the decay channel, a cut on calorimeter energy of $E < 10$ GeV in the most upstream 10 counters is applied. A study[15] of 2000 muons in the Lab E calorimeter gives a 2.3% probability that 70 to 110 GeV muons will deposit more than 10 GeV in 10 counters of the detector and a 2.5% probability that 110-150 GeV muons will deposit more than 10 GeV.

The energy development of the shower in the calorimeter is used to identify the electron or pion in events with only one muon. Electromagnetic showers begin early and are relatively short. The variable $\eta = (1-(E_{84}+E_{83})/E_{tot})$, describes the fraction of energy deposited early in a shower. Here, E_{84} and E_{83} are the energy deposited in the two most upstream counters of the Lab E detector and E_{tot} is the total energy in the calorimeter. A low cut on η isolates electromagnetic showers. To optimize efficiency, three cuts were used to identify electrons, depending on the total energy in the calorimeter: $\eta < 0.2$ for $10 < E_{tot} < 20$ GeV, $\eta < 0.3$ for $20 < E_{tot} < 60$ GeV, and $\eta < 0.5$ for $E_{tot} > 60$ GeV. From the Monte Carlo studies, these cuts maintained the pion rejection in the electron sample at 3% or less, depending on the energy, while keeping the electron acceptance at 95% or better. For the final analysis, the test beam samples of pions and electrons, covering a range of energies from 10 GeV to 100 GeV will be used to determine the final cuts and purity of the samples.

The η cut to identify electrons selects events with substantial electromagnetic energy, however these events could be due to a charged pion accompanied by photons hitting the detector. In order to reduce this background, one can use the fact that the electromagnetic shower of the photons will shift the mean of the hits in x and y away from the position of the charged track observed in the Lab F drift chambers. The studies of vertex-finding in the CCFR Neutral Current analyses have shown that the error on the shower transverse position is ± 5 cm.[18] In this study, the mean of the hit position will be required to be shifted by 3σ, or 15 cm, in x or y for the event to be cut. This is actually very conservative since the transverse extent of a hadron shower, which was used in the neutral current analysis study, is larger than the transverse extent of an electromagnetic shower. This cut will be tuned using the test beam data with radiated photons.

Source	**Estimated $\mu\mu$ events**	**Estimated μe events**
Berm Interactions	$< 1 \times 10^{-3}$	$< 4 \times 10^{-3}$
Interactions in Channel Material	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$
Helium Interactions	$< 2 \times 10^{-2}$	$< 2 \times 10^{-3}$

Table 3: *Upper limits on background events to leptonic decays from the major sources.*

1.3 Background Studies

Sources of background are neutrino interactions in the beam line berm, in the material surrounding the channel and in the helium of the channel. Neutral heavy lepton decays in the two-body $\mu\pi$ mode will be expected to cluster at a given mass. However, the three-body leptonic decays will not reconstruct to a specific mass due to the missing neutrino. Therefore it is especially important to have very low backgrounds in the leptonic decay modes. A detailed investigation of the backgrounds, based on Monte Carlo simulations, yields a background level well below 1 event for the leptonic decays. A summary of the expected leptonic decay backgrounds is shown in Table 3. A conservative estimate for the background in $\mu\pi$ mode is 1 event, where the main source is quasi-elastic scattering of neutrinos in the helium.

Neutrinos will interact in the berm material upstream of Lab F which is part of the neutrino beam line. These interactions may produce neutral particles which punch-through the absorber and enter the channel before decaying. If these particles are unaccompanied by charged partners they will not be vetoed. If they decay in a topology which fakes a neutral heavy lepton decay, then they would represent a background. In particular, K_s^0 and K_L^0 mesons could produce background events. Berm events were simulated assuming a 1% inefficiency for the veto wall using GEANT. The cuts described above were placed on the decay products and the expected rates were found to be at the level of 10^{-3} events.

A second possible source of background is from neutrino interactions in the material of the helium bags and the drift chambers of the decay channel. Approximately 3000 events are expected to occur in the material. The events of concern are “two prong events” with any number of accompanying neutral particles. Also, events with more than two charged particles can contribute if all but two charged particles miss the Lab F drift chamber acceptance. Interactions in the bag material and drift chambers are efficiently cut by requirements that the vertex be at least 20cm away from the helium bag walls and 1 m away from the drift chambers. This background is expected to be less than 2×10^{-3} events, and is limited by the statistics of the study. With further study, once the vertexing algorithm has been optimized, these requirements are likely to be relaxed, gaining more fiducial volume for the decay channel.

In the helium, 100 charged current events are expected. Seven of these events are expected to be $\nu n \rightarrow \mu\pi^{-}p$ interactions which represent an important background, particularly to the $\mu\pi$ decay mode. These quasielastic events are characterized by the muon carrying most of the neutrino energy. Therefore, the minimum energy cut of 10 GeV on showers in the calorimeter is important for greatly reducing this background. In the μe mode, the background is further reduced by requiring the pion to fake an electron, resulting in an expected background of 0.002 events based on Monte Carlo simulation of νHe scattering. For the $\mu\mu$ background, the combination of acceptance and energy cuts described above remove all but 0.02% of the events. The main sources of $\mu\mu$ background are events that have two real muons, where the second resulted from pion decays and charm production, rather than from cases where a hadron was misidentified as a muon. For the $\mu\pi$ search mode, less than one event is expected for the background given the above cuts. To reduce this further, the energy cut for this showers could be raised. However, for the sensitivity shown in Figure 1 and discussed in the next section, one background event was assumed.

1.4 Sensitivity of the New Decay Channel

The method for calculating the experiment's sensitivity to neutral heavy lepton production was developed by Gronau, Leung and Rosner (GLR).[2] The limit of the sensitivity is expressed as a function of the mass of the neutral heavy lepton, m_N, and the coupling $|U|^2$.

A Monte Carlo was written to determine the sensitivity of the decay channel. The production of mesons and the subsequent two and three body decays is simulated. The branching of the heavy meson to the neutral heavy lepton, given an assumed mass and coupling to the light neutrino, is calculated. The number of neutral heavy leptons which survive to the start of the NuTeV decay channel, traversing approximately 1300 m in distance, is determined. The number of neutral heavy leptons which decay within the detector acceptance, is calculated. The sensitivity shown below is based on decays to $\mu\mu\nu$, $\mu e\nu$ and $\mu\pi$.

The calculation of the limit of the sensitivity depends upon: the number of protons on target producing the heavy mesons, the expected level of background, the mass of the neutral heavy lepton, and the coupling to the light neutrino partner. The NuTeV expectation of 3×10^{18} protons on target was used. As discussed in the section on backgrounds above, backgrounds consistent with zero events are expected in the leptonic modes and one event is expected for the $\mu\pi$ mode. Using the leptonic modes as an example of the calculation of the sensitivity, if no events are observed, the upper limit on the number of events which could be produced, at 90% confidence level, is 2.3.[6] So the limit in mass and coupling space is the choice of those parameters which yields 2.3 events in the channel.

The resulting region of sensitivity is shown in Fig. 1. The sensitivity exceeds the previous experimental limits over a large region, and by more than an order of magnitude in some regions. Thus, with the new channel, NuTeV will be able to search an interesting kinematic for production of neutral heavy leptons.

2 Progress of the NuTeV Neutral Heavy Lepton Search

The Neutral Heavy Lepton analysis is now in progress. The decay channel was commissioned on September 1, 1996 and has been taking data without interruption since this time. This section reviews the installation of the decay channel, the status of the ongoing data collection, and the progress on the analysis.

2.1 Installation and Operation of the Decay Channel

Construction of the Decay Channel was completed by the end of August, 1997. The decay channel was designed to be an integrated part of the NuTeV detector. The veto for the decay channel replaced the original veto in the NuTeV experiment. The decay channel veto has a significantly lower rate of random firing than the original veto, reducing the veto deadtime of the experiment from 7% to 0.5%. Also, the original veto had a 2.3% inefficiency while the decay channel veto is only 1% inefficient. Triggering and readout for the decay channel were straight-forward extensions of the existing NuTeV systems. The decay channel events represented a 10% increase in the total data written to tape. Monitoring systems for Lab E drift chambers and scintillator were enlarged to encompass the decay channel detectors. Data are written to the same tapes as the NuTeV neutrino and monitoring data.

Although the decay Channel was completed three months after the start of the run for the NuTeV experiment, very little luminosity was lost. The luminosity for the decay channel will be 3×10^{18} protons on target during the ongoing Fermilab Fixed Target run. The integrated rate for the NuTeV experiment, justifying this assertion, is shown in Figure 4.

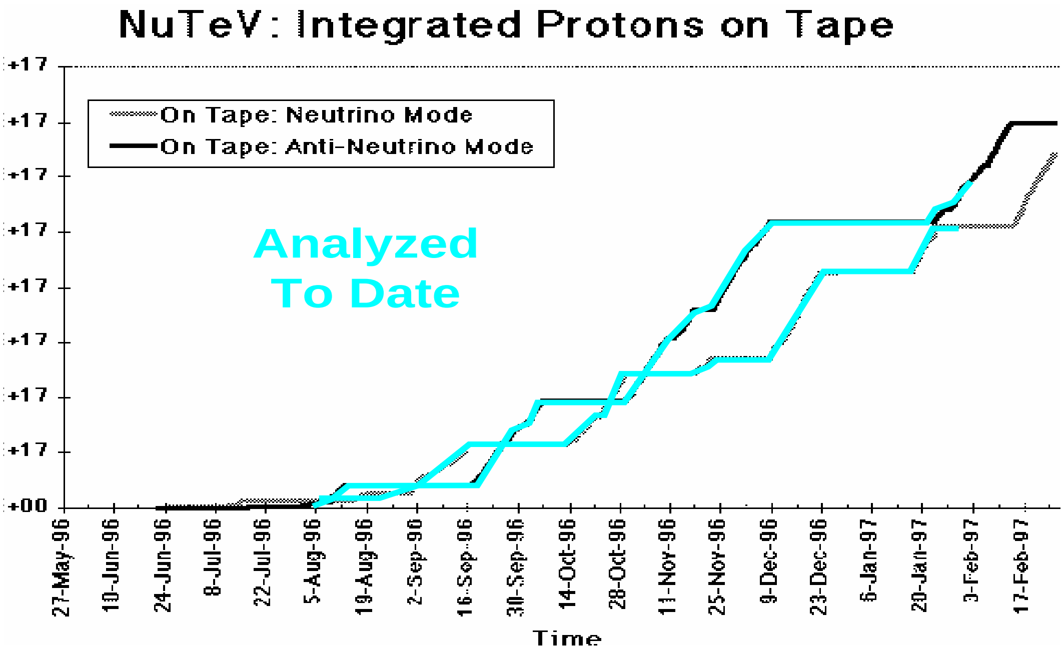

Figure 4: *Integrated luminosity of the NuTeV experiment as a function of date.*

2.2 Progress on Analysis of the Decay Channel Data

As the NuTeV data sample is run through first-pass data analysis, the decay channel events are separated. The purchases of computing resources listed above support this data split. These resources include processors and DLT drives for the separation of the data and disk to hold the final data set. Data taken through Feb 1, 1997 are presently under study.

Applying very loose cuts to the entire data sample taken between September 1, 1996 and February 1, 1997, a set of events for the neutral heavy lepton search has been isolated. These cuts consisted of requiring the physics gate and neutral heavy lepton trigger, activity in the upstream calorimeter and three or more hits in the decay channel drift chambers. Applying minimal cuts in the decay channel region permits tracking efficiency studies. A visual scan of the events in this sample divide the data into four major categories: a) single muons produced in the berm which traverse the detector at a high angle such that they miss the veto wall; b) cosmic ray showers; c) neutrino interactions in the upstream region of the calorimeter which produce a backsplash of particles into the decay channel; and d) neutrino events in the chambers of the decay channel.

Although these four categories of events are straightforward to cut to a negligible level within the decay channel sample, they represent a valuable data set for two reasons. First, these events provide an opportunity to use real data to test tracking and vertexing within the decay channel. Since January, the analysis has focussed on using these samples of events, particularly the single muon straight-throughs and the interactions in the decay channel chambers, to develop the tracking and vertexing code. Second, these events provide an opportunity to tie Monte Carlo predicted rates to actual rates measured in the decay channel. This will provide an important cross check on the background estimates which are based on the Monte Carlo.

Alignment of the decay channel chambers in x and y for the periods between September and February are complete. Improvements to the alignment by including small shifts to the angle of the chambers is underway. The alignment of the tilted chamber, providing space-point reconstruction, is also underway.

First-pass tracking code for the decay channel region has been implemented. This code was tuned on a sample of single muon events and events with identified neutrino interactions in the chambers.

Before further improvements, the code is successful for reconstructing multitrack events. This is demonstrated in Figure 5, which shows an event display of the results of first-pass tracking for a neutrino interaction in a chamber. The decay channel drift chambers are

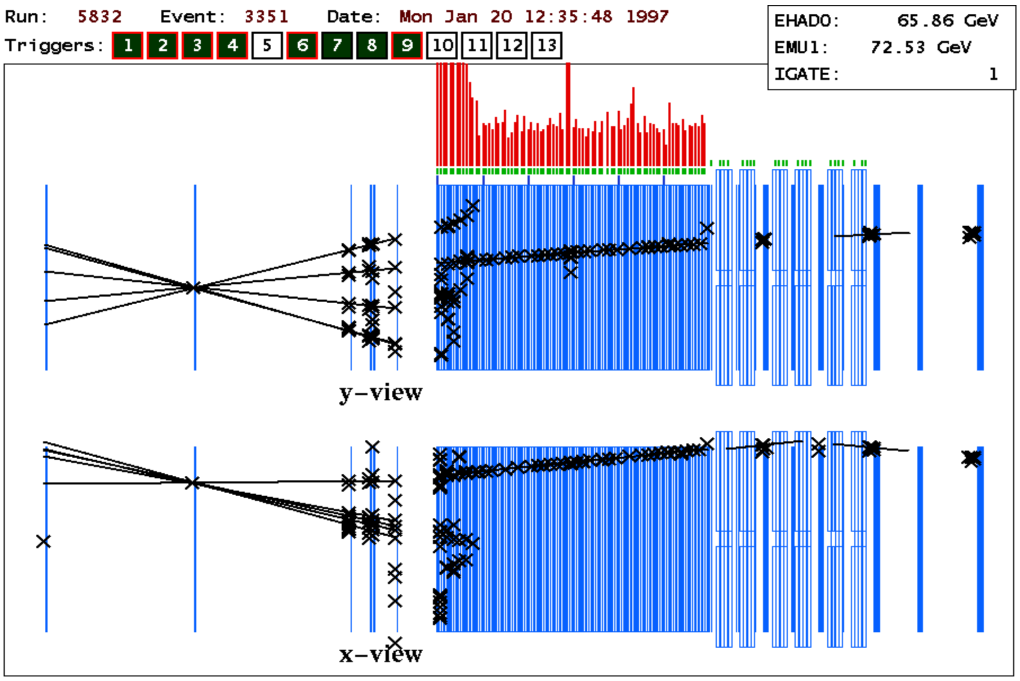

Figure 5: *Example of a neutrino event in a chamber of the decay channel. All tracks are drawn so that they extend across the entire decay channel region.*

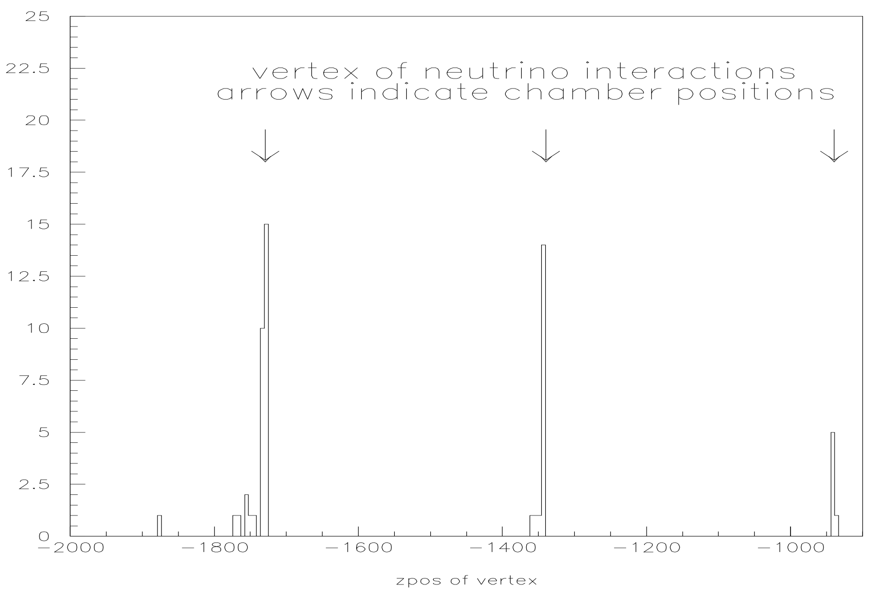

Figure 6: Reconstructed vertices in the decay channel, with chambers positions indicated by the arrows.

indicated by six vertical lines to the left. This is followed by a schematic of the Lab E detector. Crosses indicate hits in the drift chambers. The lines in the decay channel region show the tracking results. In the event display, tracks are drawn across the full decay channel region, despite the fact that there are no hits on the tracks in the most upstream decay channel chamber.

Several improvements to the tracking code are in progress. Space-point–finding code has been tuned using a Monte Carlo simulation and will be implemented as soon as the alignment of the tilted chamber is complete. Algorithms using constrained fits based on a found vertex for the tracks are also being developed.

First-pass vertex finding code has been implemented. This code uses a very simple algorithm, which will be improved upon in the future. Pairs of tracks are used to form a hypothetical vertex at the position of closest approach, which is found in three-dimensions. The remaining tracks are tested to see if they pass within cuts of this vertex position, with no hits upstream. The algorithm is repeated for tracks not yet connected to a vertex, until all possibilities have been considered. Using this code, a vertex was found for Figure 5 within 1.4 cm of the upstream face of Decay Channel Chamber 4. Figure 6 shows the position of the reconstructed single-vertex events with two or more tracks for a small, general sample of the decay channel data. The position of the chambers is clearly observable due to the reconstructed neutrino interactions in the event sample. Within this limited sample, no two-track events within the fiducial volume (hence neutral heavy lepton candidates) were found.

Data from the NuTeV test beam will be used to tune the particle identification cuts used in the neutral heavy lepton analysis. The test beam uses a Cerenkov counter and transition radiation detectors for particle identification. The electron beam has been measured to be $> 99\%$ pure. The hadron beam is 91% pions. The remaining content is consistent with being hadrons, but is not identified by our particle identification detectors. Each of these beams is sufficiently pure to allow tuning of the particle ID cuts for this analysis. Data are available over a range of energies from 50 to 100 GeV. Low energy running, with data taken in the 10 to 50 GeV range, is expected to occur in May. The identification of electrons and pions in the neutral heavy lepton analysis is based on a cut on the shower shape variable, η, which was explained above in the discussion on backgrounds. Electrons are expected to have a low value of η while pions will have larger values of η.

Goal	**Expected Completion**
Final tracking and reconstruction code	end of summer, 1997
Particle identification cuts defined	end of summer, 1997
μ-mode background simulations	end of summer, 1997
Production Monte Carlo update	autumn, 1997
Complete split of NHL data	autumn, 1997
Goal for results on μ-mode search	*summer, 1998*
$ee\nu$ and $e\pi$ background studies	summer, 1998
Further particle ID studies	summer, 1998
Search for $ee\nu$ and $e\pi$ decays	academic year 1998-99
Goal for results on $ee\nu$ and $e\pi$ decays	*summer, 1999*

Table 4: *Milestones for the neutral heavy lepton analysis.*

Table 5 provides an overview of the milestones for the Neutral Heavy Lepton Analysis. The goal is to complete the neutral heavy lepton search by summer of 1999.

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