Searches for the Cowan Effect–A Peak at 21 hr LST for μ-e Decay Events

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Abstract

In several 1960's experiments Clyde L. Cowan's group observed μ-e-decay events with a sharp, statistically-significant intensity peak near 21 hr LST (denoted the Cowan Effect). The zenith happened to be near 39 deg N and 21 hr RA, close to the direction ($\sim$47 deg N, $\sim$21 hr RA) of our galactic spiral arm and of the Sun's motion in the galaxy. The μ-e-decay detectors were omnidirectional, but the response would be strongly peaked at the zenith if the atmosphere highly attenuated the primary particles. If galactic dark matter (DM) includes a nonrotating, strongly-interacting component (SIMPs), it would arrive at Earth as a highly directional "wind," peaking at 21 hr LST- -a huge Compton-Getting Effect for DM $\frac{v}{c} \sim 1/1000$. Peaks near 21 hr LST in brief low and high altitude Arizona experiments and in cosmic ray data from the LSND experiment are presented.

1 Introduction:

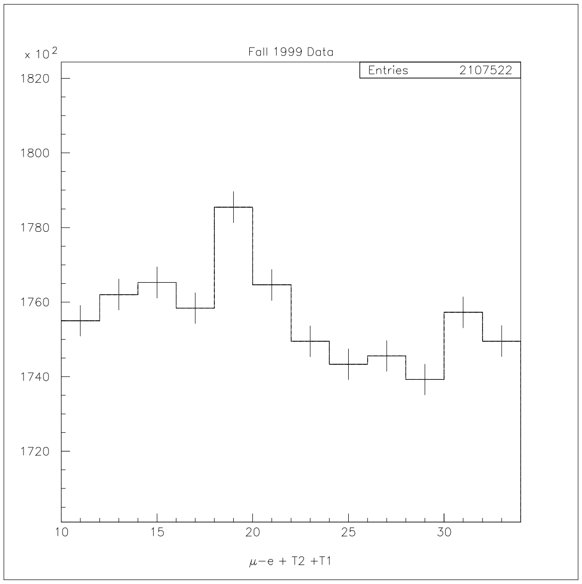
We present the early results of a cosmic ray search for dark matter at mountain altitude. For 3 years, we have been studying a sidereal time dependence of the cosmic ray stopping muon rate. Recently, we completed two data taking runs with an 820 kg liquid scintillation detector at 2700 m near Tucson, Arizona. Stopping muons were counted in the detector by searching for a muon- electron signal pair with 127mm PMTs, the decay electron following from .6 to 6 μs after a muon signal. Data was manipulated by the use of cuts on the zenith acceptance angle, collimating with two plastic scintillation detectors placed above the main liquid tanks. Further cuts were made to limit the decay electron energy to its maximum cut-off. In addition we present an independent analysis of cosmic ray stopping muon data from the Liquid Scintillator Neutrino Detector (LSND) at Los Alamos National Labs.

We started the search with a priori knowledge of experiments Clyde Cowan had done in the early 1960's at Catholic University in Washington, D.C. He saw an unexplained peak in the stopping muon rate in his liquid scintillation tank when plotted in Local Sidereal Time. We have attempted to confirm his results with better statistics, as well as explain them, perhaps, in terms of dark matter.

2 Analysis of Cosmic Ray data:

An early, preliminary search utilized a liquid scintillator target 0.45 m by 0.45 m and 0.68 m high located on the top floor of the physics building 1.2 meters above floor level. A 0.82 m square plastic scintillator was placed 0.28 m above the liquid surface (Counter T). The experiment was operated for 148 days. When data from the combination μ-e Tbar (i.e., Counter T in anitcoincidence) was plotted in 2-hour sidereal time bins, the 20-22 hr Local Sidereal Time (LST) bin showed a 0.4 percent peak (2.3 standard deviations) relative to the renormalized, smoothed μ-e T histogram. This result encouraged us to construct four more modules for use on Mount Lemmon.

2.1 Analysis of Mt Lemmon Cosmic Ray data: This search utilized four targets in a square array, each 0.58 m by 0.58 m and 0.69 m high located in the University of Arizona High Altitude Laboratory where the atmospheric depth is 750 g/cm^2. Counter T1 (0.6 m square plastic scintillator) was located 1.86 m above the liquid surface centered on the four module array. Counter T2 (0.82 m square) was located 1.15 m above the liquid surface, also centered on the array. At present, data includes 30 days uninterrupted running in November and December 1998, plus a very recent 20 days uninterrupted run in April and May of 1999. The timing of these two runs were such that a daily CR muon variation due to atmospheric conditions would shift 12 hrs when plotted in sidereal time. Adding these two runs together would roughly cancel any civil time variations since LST and Mountain Standard Time would shift 180 degrees.



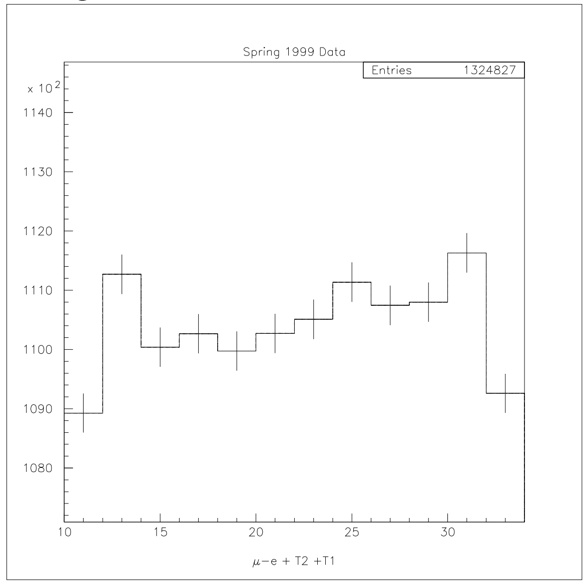


Figure 1 shows an LST plot of T1 + T2 + μ-e decay event totals in 2hr bins from data taken November 7 to December 7, 1998. A total of 2.11×10^6 events are plotted from 27.7 million μ-e triggers, with a fairly constant rate of 925,000 per day. This daily rate changed inversely with the barometric pressure. A scale with the sidereal day running from 10 hrs to 34 hrs was chosen to make our region of interest (21 hrs LST) prominent. This conversion simply starts each day at 10 hrs LST, then, when 24 hrs LST is reached, instead of starting over to 0 hrs, the day is let run 10 more hours. The prominent peak at 18-20 hrs LST might be a candidate for the peak Cowan saw in 1965. Current data puts the peak at 1.3 percent above the average of the two bins on either side (i.e., 16-18 hr and 20-22 hr).

Figure 2 shows data from April 20, 1999 to May 9. For the 20 active days, 17.8 million events were collected with an average of 890,000 events per day. As there is no peak in the 18-20 hr LST bin, the peak in Figure 1 may have been correlated with solar time, and has moved to the 30-32 hr LST bin.

2.2 Analysis of Los Alamos Liquid Scintillation Neutrino Detector data: The LSND lab is located under 2000 g/cm^2 of iron and concrete at 2100 m elevation. In order to calibrate the equipment, it was sometimes run for several weeks on cosmic-ray-generated μ-e decays. The experimenters kindly made this data available for additional analysis by the Arizona group. The vertical cosmic ray muons stopping in LSND would enter with an initial energy of 3 GeV in contrast to typically 70 MeV in the Arizona experiments. LSND provided information on the location and inclination of each stopping muon track exceeding 10 cm. Some muons leak in through less shielding near the endcaps of the detector, so endcap μ-e decay events were not included in the Arizona analysis.

Figure 3 shows the results of a careful analysis of 8 days of August 1997 LSND cosmic ray stopping-muon data. A 2.3 σ enhancement is observed of 12.7 $\pm$ 5.5 events per 20 minutes in the 2 hour bin centered at 21 hrs LST, as compared to the average of the other 11 LST bins. The events in Figure 3 were cut to only accept muons originating within 32 degrees of the zenith and to reject muons entering the LSND detector through the endcaps. Because LSND was often taken off-line for short periods, the number of events in each acceptable 20 minute data segment was required to fall within 3σ of the full 20 minute data segments.

No 21 hr LST enhancement appears in the data without some cut on zenith angle – but, when we further restrict the zenith angle so as to cut out those events with zenith angle less than 22.3 degrees, the 21 hr enhancement remains, with similar significance. With an additional azimuthal angle cut restricting the muons to originate from the eastern sky, we reduce the 21 hr LST signal from LSND approximately to 1.3 σ, and likewise for a western sky cut. When we use the 22.3 to 32 degree zenith angle cut, and restrict the muons to come from the southern sky, there is only a 0.9 σ 21 hr LST signal, but, when we restrict the muons to come from the northern sky, the 21 hr signal is at a level of 2.0 σ. The preference for events to come from the North is consistent with the earth-sun apex being at 47.6 degrees North declination (compared to the declination of zenith (latitude) at Los Alamos of 35.87 degrees).

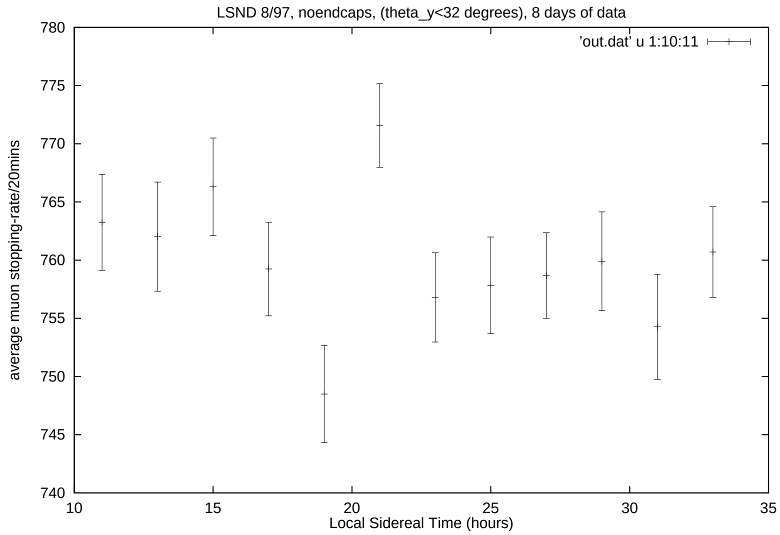


Figure 3: Stopping muon rate in sidereal time

3 Conclusions

It is disappointing that the statistically significant peak in the November - December run shown in Figure 1 is totally absent in the April - May run shown in Figure 2, and the peak in the 30-32 hr LST bin may have the same (unknown) origin - near midnight Mountain Standard Time. On the other hand, it is also possible, since the Sun + Earth velocity is a minimum on December 4th and a maximum at 13 % higher velocity on June 2nd of each year, that the muons in the Fall passed through the detector in the Spring. In terms of finding the Cowan Effect, a longer, continuous run is needed since the amplitude might vary with time of year. However, absence of a peak would be consistent with our not observing any evidence of the Cowan Effect for vertical muons in Tucson, and our interpretation [Bowen, 1999] that Cowan's group was observing muons entering his experiments at 30 degrees or more. Interestingly, in the Spring 1999 data, the T2 + μ-e decay histogram (not shown) does have a $\sim 1\sigma$ peak in the 20-22 hr LST bin.

The 21 hr LST peak in LSND cosmic ray data gives a hint that the Cowan Effect may extend to muons with energies above 3 GeV.

4 Acknowledgments

We gratefully acknowledge assistance from many colleagues: John Rutherfoord, Michael Shupe, Joel Steinberg, and Leif Shaver of the Arizona Experimental Elementary Particle Physics Group for the use of their group's computer facilities and borrowed items of electronics; Mike Eklund, Systems Administrator for the Department of Physics for providing invaluable computer support, Anson Nicol, a Pima College - NSF bridge program student for assistance in construction of the mountain μ-e detector; Michael Lloyd-Hart of the Steward Observatory Center for Adaptive Optics for substantial computer resources; and Jonathan Ormes and Robert Strietmatter of Goddard Space Flight Center for the loan of the 127 mm PMTs. One of us (A.G.Y.) received support from a Pima College-NSF grant for Summers 1996, 1997 and a NASA Undergraduate Intern grant during the 1996-1997 academic year.

We also thank Bill Louis, Rex Tayloe, and Gaurang Yodh for providing us with cosmic ray muon data from the LSND collaboration, as well as for spiritual and technical assistance with the data.

All mountain-altitude data analysis was done using CERN's Physics Analysis Workstation program.

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