Calibration of AMANDA with Coincident Events from SPASE-2

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Abstract

A subset of the air shower events triggering SPASE-2 produce high energy muons that are observed by AMANDA. These coincident events are being used to calibrate several aspects of the AMANDA-B detector: pointing accuracy, ice properties, and, in the future, string location and energy resolution. The procedures for doing such calibrations are described. Results and implications for AMANDA performance will be presented at the conference.

1 Introduction

SPASE-2 (Dickinson et al., 1999a) and AMANDA-B (Hill et al., 1999, Karle et al., 1999) have been running in coincidence mode since February, 1997. On every SPASE-2 trigger a signal is sent to trigger AMANDA. The coincident events are matched offline via GPS times. The primary goal is determination of cosmic ray composition in the knee region, in conjunction with the VULCAN array (Dickinson et al., 1999b). The coincidence data provides a tagged beam of muons useful for investigating various aspects of AMANDA, including pointing accuracy and ice transparency. Such calibrations provide a useful test of AMANDA performance, as such parameters could otherwise be determined only via Monte Carlo. This is a unique advantage for AMANDA, as no other existing or planned large high energy neutrino telescope is located near an air shower array.

2 AMANDA-B10 Pointing Calibration

SPASE-2 events provide a sample of muons whose directions are measured independently from any AMANDA analysis. A set of SPASE-2/AMANDA-B10 coincidence events has been reconstructed by both arrays and the resulting pointing directions compared on an event by event basis. A similar procedure was performed for a sample of SPASE-2/AMANDA-B4 data from 1996, and is described by Askebjer, et al. (1999). The pointing resolution of AMANDA-B10 can thus be tested, as the pointing resolution of SPASE-2 is known from both Monte Carlo and subarray comparisons (Dickinson et al., 1999a).

First, the directions and core locations of the SPASE-2 events are determined by SPASE-2 analysis, and events passing within 20 degrees of the direction of AMANDA-B are matched with AMANDA data. We expect cosmic ray protons at the threshold of SPASE-2 ($\approx$ 100 TeV) to generate an average of 1.2 muons that penetrate to the depth of AMANDA-B, following very nearly a Poisson distribution (Gaisser, 1990). Next, the AMANDA direction is reconstructed and the cuts described in Karle et al. (1999) are made, with the exceptions that no initial filtering is done and no cut is made on zenith angle. Analysis is currently underway and the results concerning AMANDA pointing accuracy will be presented.

In addition to SPASE-2, the SPASE-1 air shower array was operated at the South Pole from 1989 to 1997. SPASE-1 coincidence events arrived at different angles than SPASE-2 events (average zenith and azimuth angles of 27° and 337° for SPASE-1/AMANDA-B10, as compared to 12° and 243° for SPASE-2/AMANDA-B10), allowing us to check for angle dependent reconstruction effects. Analysis of SPASE-1 coincidence data from 1997 is currently underway and will also be presented.

3 Ice Transparency

3.1 Method Of great importance to AMANDA are the optical properties of the South Pole ice at depths of hundreds of meters. Several methods are used to measure ice transparency at AMANDA depths, including

[1]See OG 1.2.05 for a complete list
[2]See talk of F. Halzen (HE 6.3.01) for a complete list

several in situ light sources and downgoing muons (see Woschnagg et al., 1999). Coincidence data have also been used to measure ice transparency.

On every event, the air shower core location and direction were reconstructed by SPASE-2. This SPASE-2 track was then propagated down to AMANDA, and the impact parameter to every optical module in AMANDA was determined. The probability of each module being hit was determined as a function of impact parameter, averaged over the entire data set. An exponential fit to the falloff of hit probability with impact parameter was made for every working module, giving an attenuation parameter for each. Note that the attenuation parameter fit here is defined differently than either the absorption or attenuation lengths determined in other AMANDA analyses, and cannot be compared to either directly. Therefore, only relative attenuation at different depths is presented. The fit was done for the impact parameter range from 20 to 150 m, where the averge hit probability was observed to be much less than 1.0 and therefore not affected by saturation. The resulting attenuation parameters were then binned by optical module depth. The advantage of this method is that there is no AMANDA self-trigger involved, so all AMANDA trigger biases and most systematic effects are removed. It is important to have many such transparency measurement techniques with different systematics.

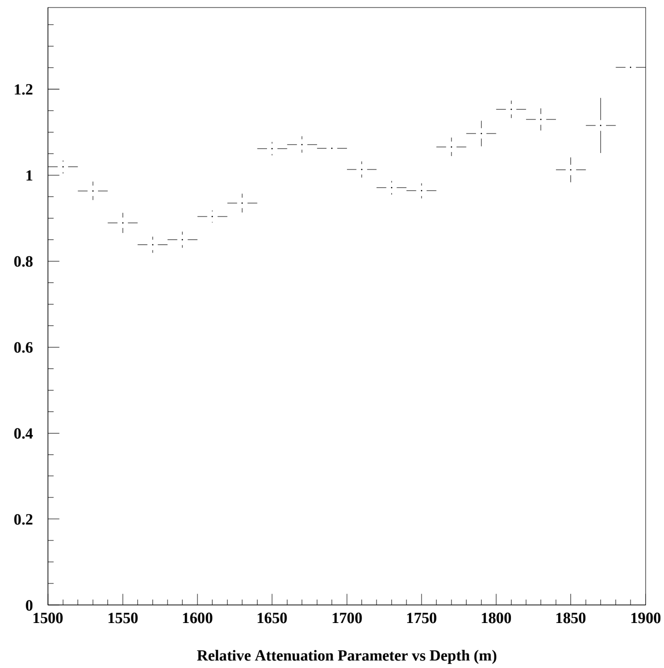

Figure 1: Relative attenuation parameter as a function of optical module depth, using SPASE-2/AMANDA-B10 coincidence data. The dips at 1570 and 1750 m are in agreement with the predictions of He and Price (1998) and with other measurement methods.

3.2 Results The relative attenuation parameter as a function of optical module depth is shown in Fig 1. Peaks in absorption (dips in attenuation parameter) are seen at 1570±20 and 1750±20 m, in agreement with the predictions of He and Price (1998) and measurements made by AMANDA with in situ laser pulses (Woschnagg, 1999) and muons from AMANDA-A/AMANDA-B coincidences (Young,1999).

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