Relativity on a mountain

Alan Walker describes how a schoolgirl from Scotland used steel and scintillator to test Einstein's special theory of relativity.

Studying cosmic rays from mountain tops has a grand tradition with famous observatories in dramatic surroundings, such as the Jungfraujoch in Switzerland, the Pic du Midi in France and Mount Chacaltaya in Bolivia. Last year one of Scotland's highest mountains, Cairn Gorm, temporarily joined the elite club when Ingrid Burt from Beeslack High School in Penicuik, near Edinburgh, set up a high-school cosmic-ray project. Rather than measuring cosmic-ray showers, as many schools projects are now doing (see p19), Burt set out during World Year of Physics to test Albert Einstein's special theory of relativity.

Burt spent six weeks funded by a Nuffield Bursary looking at the feasibility of doing such an experiment with a small muon detector, using a UK mountain. Peter Reid from the Scottish Science and Technology Road Show and myself of the Particle Physics Group at the University of Edinburgh guided her studies. The study and the subsequent experiment were undertaken in conjunction with the Particle Physics for Scottish Schools outreach project, which also provided the detector. The aim was to verify time dilation by comparing the number of cosmic-ray muons detected near the top of the mountain at 1097 m with the number arriving in the university 76 m above sea level.

The amount of dilation depends on the particle's velocity, so a key part of the experiment was to ensure that the muons detected in the physics department at close to sea-level had the same speed when they passed the altitude of Cairn Gorm as the muons actually detected on the mountain. To do this we used steel sheets to slow the muons until they stopped in a thick scintillator detector and subsequently decayed. The "signal" was thus a pulse in a thin counter from a muon entering the apparatus followed within 20 μs by a delayed pulse from the exiting electron created in the muon's decay.

For a student in Edinburgh, Cairn Gorm was a clear choice for an experiment at altitude. It is only 227 km from Edinburgh and, like the Jungfraujoch, has a mountain railway – an important criterion where heavy equipment is involved. To this end, Burt asked CairnGorm Mountain Ltd, the company that operates the funicular railway, for help in transporting the 400 kg of steel and other apparatus.

We took the first measurements at the Ptarmigan Top Station of the Cairn Gorm funicular railway, where we needed 49.3 cm of steel to slow the muons so that they would stop and decay in the scintillator. Given that we can calculate the energy losses in both materials, this accurately measures the velocity of the muons as they enter the top of the steel at this altitude before they stop and decay in the scintillator.

The energy lost as a muon of this velocity passes through the atmosphere can also be accurately calculated, so we compensated for this loss between the Cairn Gorm and university sites by removing 21 cm of steel – the equivalent to the slowing power of the intervening 1021 m of atmosphere – and ran the experiment at the university with 28.3 cm of steel. This meant that the muons detected at both experimental sites had the same energies and speeds. As muons travel down from Cairn Gorm to the university, they change velocity and their numbers reduce according to the exponential decay law. The number of muons detected each minute decreases as they travel downwards, and the reduction depends solely on the time elapsed. Without the effect of time dilation, the reduction in this experiment would be a factor of about 4; taking time dilation into account gives a reduction factor of 1.3.

Ingrid Burt (right), with Fiona Milligan of CairnGorm Mountain Ltd and Alan Walker, with the experiment's kit. (Courtesy Peter Reid.)

For 10 days in October 2005, visitors arriving at the top of the Cairn Gorm funicular had the chance to see the experiment in action as it counted stopping muons there – at a rate of 1.3 a minute. This meant that if Einstein was right, we should detect 1 a minute at the university, and it was no surprise to do so.

Burt is now refining these calculations to estimate the errors in the predictions, but we do not expect these to render the results invalid. It would be interesting to repeat the experiment with a greater height difference, for example at CERN and at the top of Jungfraujoch railway.

● Ingrid Burt was a gold finalist at the British Association 2006 Crest Science Fair, and won a week at the London International Science Fair in August.

Résumé

Relativité dans les Highlands

Pendant 10 jours, en octobre 2005, les visiteurs arrivant au sommet du funiculaire de Cairn Gorm ont pu découvrir une expérience sur les rayons cosmiques, réalisée par une lycéenne. Ingrid Burt, élève d'un lycée écossais, a voulu, à l'occasion de l'Année mondiale de la physique, vérifier expérimentalement la théorie de la relativité restreinte d'Albert Einstein. Au moyen de tôles d'acier et d'un détecteur à scintillation, elle a étudié le phénomène de dilatation du temps en comparant le nombre de muons issus du rayonnement cosmique arrêtés par l'appareil au sommet de la montagne avec le nombre mesuré au niveau de la mer.

Alan Walker, *University of Edinburgh.*