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The Special Theory:

Disproved by Flawed Experiment Measuring Muon Decay Times

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Introduction

One of the most famous experiments [1] in history was hailed as strong evidence in favour of the Special Theory of Relativity (SRT), but this paper explains clearly how that experiment was mal-performed, thereby offering evidence against the theory rather than for.

The Experiment [2]

The experiment was designed to test the essential claim of SRT that moving clocks run slow relative to observers described as stationary. Otherwise referred to as the 'Einstein Time Dilation', this claim is defined by the expression $\sqrt{(1-v^2/c^2)}$ where v is the speed of a clock relative to its observer. It is well known that the speed of clocks would need to approach that of light for this temporal dilation to be of sufficient magnitude to detect, so the average rate at which muons decay having entered the Earth's atmosphere at speeds at around 99% of $\boldsymbol{c}$ was investigated. If the theory is valid, these natural moving clocks should run at about $1/9^{th}$ the rate at which they would operate when at rest relative to us. To test this comparison, decay times of many muons halted within a plastic block on top of a mountain over the course of an hour were used to predict how many should have reached sea level if they had decayed in the same way had they been allowed to continue with the mountain removed. The apparatus was then moved to near sea level to check this prediction by counting the real rate at which muons reach that depth in the Earth's atmosphere. The following procedure was declared: -

1. Detect muons.
2. Distribution of decay times will be used as clocks.
3. Measure time dilations.

The experiment was demonstrated on film for corroboration by Professor David H. Frisch of the Massachusetts Institute of Technology and Dr James H. Smith of the University of Illinois. Apparatus was set up and readings taken as follows initially at an altitude of 6,300ft above sea level within a hut near the summit of Mt Washington in New Hampshire, USA.

4 identical cylindrical blocks of special opaque plastic were glued on top of one another to form a cylindrical scintillator (SLR) with its axis vertically orientated. This measured approx. 1ft high × 1ft diameter. It was described how every muon passing through this material was producing a flash of light on entry. But as those flashes were too dim to be recorded by a normal camera, a photo multiplier (PM), which contains a sensitive photocell, was first secured onto a stand to support the SLR to thereby detect the flashes and convert them into usable electrical signals. A close-fitting cover of aluminium foil was then placed over the SLR and its bottom edge linked to a small foil sheet previously placed between the PM and its stand. The foil was intended to enhance the intensity of light for detection by reflecting flashes within the SLR. A cloth sheet was then placed over the entire arrangement and taped around the base of the SLR to prevent ingress of room light. The PM had a voltage input supply cable and an output signal cable connected to an amplifier, which in turn was connected to the trigger of an oscilloscope (scope). When voltage was applied, the flashes created by muons entering the SLR were registered by the PM, which passed signals indicating those events to the scope via the amplifier. The scope's electron beam then swept

rapidly across the screen every time a signal was received. A second cable was also linked from the amplifier's input connection from the PM to carry signals directly (without amplification) to the scope's vertical reflection plate so that pulses starting sweeps were visible on the screen. Only the uppermost left-hand point on the display screen would be (momentarily) illuminated between sweeps. At this point, the vast majority of sweeps indicate the passage of muons straight through the SLR. The pulses displayed were of varying depth, as muons passed through differing distances of plastic, e.g. some through corners of the SLR and others the full height. A grid for measuring was included within the screen. This grid comprised 9 equidistant vertical lines representing 9 periods of 1μ-sec along the horizontal axis. While exposed to a rain of unrestrained muons, the rate at which muons were entering the SLR was so intense that there appeared to be a constant succession of sweeps.

The electricity supply was disconnected and the SLR and PM were pushed between two piles of wooden blocks supporting a board carrying a stack of iron blocks. This stack was 2½ft high × approx. 4ft sq. Prof. Frisch claimed "we know how far charged particles of a given mass can travel through matter", so a calculation based upon that knowledge was applied to determine the required depth of iron to bring many muons to a halt within the SLR immediately below the iron. He stated that given this depth of iron, muons travelling at 0.9950c immediately before entering the iron would be brought to rest in the top of the SLR, whereas those at 0.9954c would stop in the bottom of the SLR. Any muons travelling slower than 0.9950c would be trapped within the iron before reaching the SLR and any faster than 0.9954c would continue through the SLR and into the mountain. This means that a deeper SLR would have captured more muons. He stated "Most muons shoot straight through the SLR".

It was noted that when a positive muon decays, it emits a neutrino, an anti-neutrino and a positron, which was thought to produce a second flash and thereby explain secondary pulses on the scope to record the durations of muon decay.

The electrical supply was re-connected to show that there were fewer sweeps than before, as the iron would have been stopping some muons before entering the SLR as predicted. Most start pulses continued to be singular events indicating passage of most muons straight through the SLR, but there were occasional secondary pulses marking disintegrations as a consequence of decay. The scope display was paused for the purpose of explanation by Dr Smith immediately following a secondary pulse to show that the start pulse for one muon was also still visible, which would momentarily apply for all sweeps. It was noted that the time taken by a muon to stop was negligible on the scope's scale and sweep times equated to decay times when decays took place. It was also recognised that decay times varied considerably, so a large number of them would be required to establish a pattern to use muons as clocks. This was made easier by moving the starting line to the left behind a vertical mask and the sweep traces upward behind a horizontal mask within the screen, so that only occasional decay pulses were visible and available for recording. A Polaroid camera was attached to the end of a mounting fixture secured to the scope's display screen. Another photo multiplier (PM), smaller than that placed below the SLR, was attached over an aperture in the upper face of the mount to register decay pulses. It was noted that the camera could photograph about 20 consecutive decay flashes on one exposure with the shutter left permanently open.

The second PM was used to react to decay flashes from the scope and send secondary pulses to a register via cables in and out of the amplifier. In this way, only decay pulses were to be counted on the register. Power was initially supplied to the camera and the second PM for five pulses to be counted by the register to provide a preliminary demonstration. The film was removed from the camera to show an exposure of the five pulses (with starting pulses absent through masking), ref. fig.1. The horizontal distances of these photographed pulses from the border on the left were used as measurements of decay times, which were then drawn as vertical lines on a chart with their starting points in horizontal alignment, ref. fig.2.

Figure 1

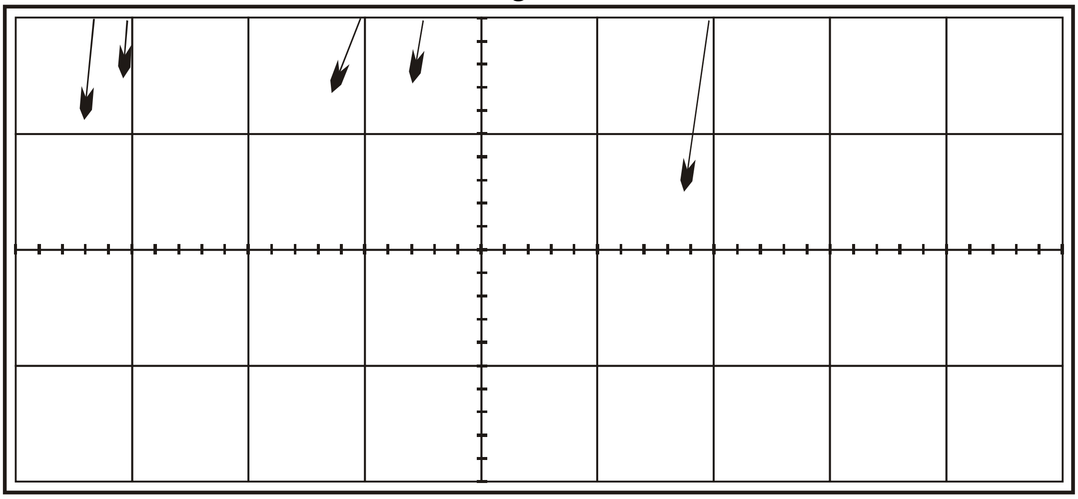
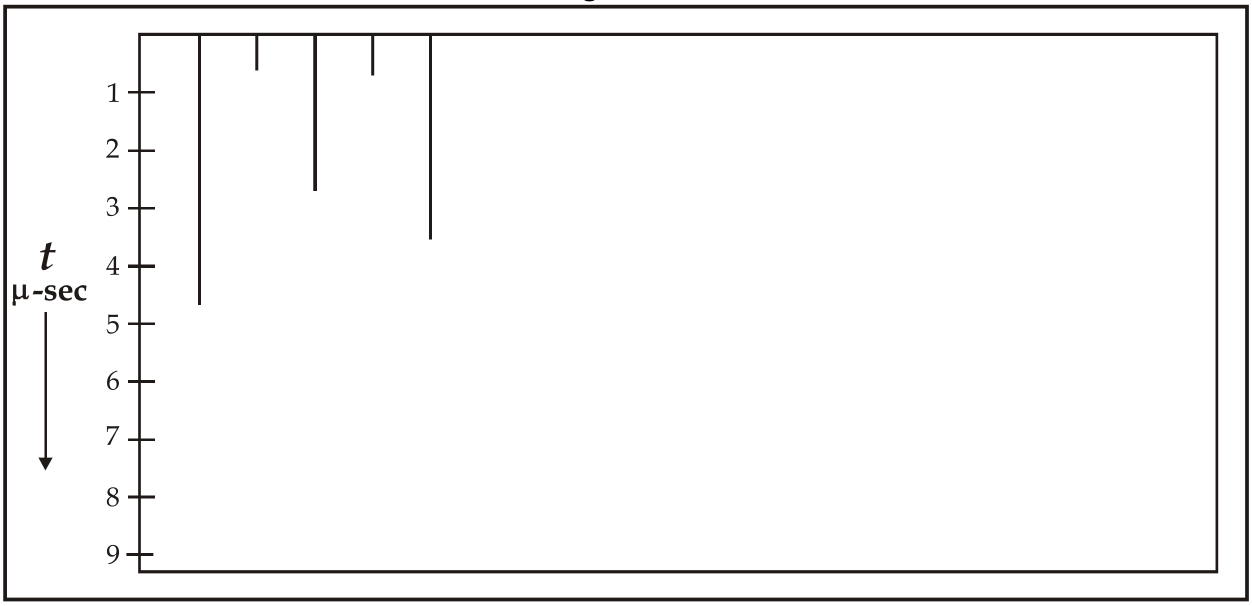


Figure 2



Electrical power was applied to all devices to commence monitoring the decay of muons for a period of 1 hour, which demanded changing the camera film every time a further 20 decays of muons were registered. The total registered was 568. It was noted that five previous one-hour periods of similar observation resulted in counts of muon decays ranging from 527 to 588, giving an average of 564, so the experimenters were satisfied that observations of 568 for one hour were representative of a rain of muons constantly entering the Earth's atmosphere and reaching the same sized block of plastic at that altitude. The team transferred all 568 lengths measured on the film exposures onto the chart illustrated by fig. 2. The result showed that many decayed when at rest in the SLR within 1μ-sec, but fewer within 1-2 μ-sec's and so on until very few survive the full 8 ½ μ-sec visible on the scope face for recording on the chart.

It was claimed that these times could be used to predict how far those muons should have travelled at near the speed of light had they not been stopped. For example, it was calculate that a muon shown to have lived for 3.5 1μ-sec at rest within the SLR should have travelled 3.5 $\times 10^{-6}$secs × v if it had not been stopped, where the velocity of the muon v had been calculated to have been between 0.9950c and 0.9954c as previously explained. But this degree of accuracy was considered unnecessary, so v was taken to be 1000 ft/μ-sec, as this approximates c. The predicted distance for one particular muon without applying the Einstein Time Dilation was therefore calculated to be $3.5\times 10^{-6} \times (1000\text{ft}/10^{-6})$ = 3,500ft. To simplify prediction using the many distances drawn on the chart, a distance (or height) scale was placed over the time scale on the chart where 1μ-sec = 1000ft. A string was then pinned across the 6,300ft level to discover 27 lines extended below that distance, meaning 27 muons should have reached sea level before decaying in the same way as if at rest.

All apparatus was moved to facilities near sea level at Cambridge, Massachusetts and set up in exactly the same way, but with one exception; the stack of iron was reduced in height by 1ft from 2½ft to 1½ft, as it was claimed that this reduction of matter compensated for the increased height of air above the apparatus, so that the slowing effect would be the same. This meant that the muons halted would have had the same speed when passing 6,300ft, (i.e. 0.9950***c*** - 0.9954***c***) as those captured at that altitude. It was then stated that other factors had been taken into account to ensure constancy of effects from the original site up Mt Washington to that near sea level, but were considered to have been negligible; such as: -

1. Not all cosmic rays are vertical.
2. Other muons are created between 6,000ft and sea level.
3. Some muons that stop in the SLR make nuclear reactions.

The apparatus was activated for one hour, during which time 412 muon strikes were recorded rather than the predicted 27 if they had been at rest relative to us. This corresponded to 0.7m/s on their chart, or 0.7/6.3 = 1/9th of rest time, or an altitude of just 700ft according to the moving frame of a muon

NOTE: - The term mu-mesons was used in the referenced film rather than muons in line with the terminology of the day, so quotes have been adjusted accordingly.

Summary of Results

Altitude	Depth of Iron in feet	Total Muon Decays	Muon Decays of 6. 3 μ-secs minimum duration
6,300 ft	2 ½	568	27
Zero	1 ½	412	Not given

Miscalculation

The experiment was founded upon a sound concept and apparently well-performed in general, but a fundamental element was miscalculated to a considerable degree.

To almost stop muons before they entered the SLR, 2½ ft of iron was deemed necessary at 6,300ft where they were calculated as having been travelling at between 0.9950***c*** and 0.9954**c** upon entry into the iron, and 1ft less iron at sea level where they would have been travelling at a lesser speed having passed through a distance of 6,300ft more air. It was admitted "most muons shoot straight through the SLR" so would have had speeds greater than 0.9954***c***, giving a greater intensity of muons travelling above that speed. Therefore, it was extremely important to reduce the height of iron by the correct amount required to compensate exactly for the slowing effect of air between sea level and 6,300 feet, otherwise a batch of muons of greater or lesser intensity could be captured at sea level that would not have been captured by 2½ft of iron at that altitude. In order to ensure those muons halted at sea level had been travelling at the same speed as at 6,300ft, the masses of overhead air should have been compared accurately to ascertain the atmospheric dragging effects, but were not.

The aim of the following table is to use generally accepted approximated data regarding the Earth to calculate and compare the masses of air above equal surface areas at the two sites and thereby check that the heights of iron used were correctly proportioned. This was necessary to result in the capture of muons that had been travelling within the same range of speeds when entering the Earth's atmosphere to ensure batches of equal intensity. The process of calculation may be described thus: -

1. A given mean radius of geoid confirms the volume and surface area.
2. The surface areas of the geoid and a sphere at the alt. 6,300ft (1,770m) are calculated.
3. By dividing a given total mass of air by the geoid surface area, the mass of air above every square meter at sea level is calculated.
4. From given approximate densities of air at 1,770m (assuming nominal conditions) and sea level, the mean density of air between those levels is calculated.
5. Earth's geoid volume is subtracted from the volume of a sphere with radius increased by 1,770m to give the volume of air below that altitude, which is then multiplied by the mean atmospheric density between those levels to give the mass of air for below that altitude.
6. The mass of air below alt. 1,770m is subtracted from the total mass to give the mass of air above altitude 1,770m, which is then divided by the surface area at alt. 1,7770m to give the mass of air above every square meter at that altitude.
7. The proportion of air mass above every square meter at sea level to that above altitude 1,770m is found by dividing the mass of air above every square meter at sea level with that at alt. 1,770m.
8. The increase in air mass above every square meter at sea level to that at altitude 1,770m is calculated by subtraction.
9. The proportional increase in air mass above $1m^2$ at sea level to that at 1,770m is found by dividing the increase described by (8) by the mass per square meter at alt. 1,770m.
10. The height of iron that should have been removed at sea level is calculated by multiplying the height of iron used at alt. 1,770 by the proportional increase of air mass above every square meter at sea level.
11. The height of iron that should have been used at sea level is obviously calculated by subtracting that which should have been removed from that which was used at alt. 1,770m.
12. The proportions of discrepancy in the height of iron used were then calculated.

The following principles are recognised with this process: -

a) The density of iron remains constant for both sites.
b) The density of air changes with altitude but is irrelevant for observations at sea level, as Earth's surface area and total mass of air are
c) given.
d) The changing density of air between sea level and 1,770m is relevant, as a mean value is required to calculate mass for deduction from the total to determine the mass per square meter above the site on Mount Washington.
e) Iron and air may not slow muons at the same rate given equality of mass and column base area.

Feature	Term	Equation	Calculation	Value/Result
Mean geoid radius	r_g	NA	NA	6,371,000 m [6]
Radius at altitude 6,300ft (1,770m)	r_a	r_g + 1,770	6,371,000 + 1,770	6,372,770 m
Geoid volume	V_g	$4/3 \times \pi\, r_g{}^3$	$4/3 \times \pi\, 6{,}371{,}000^3$	$108.321 \times 10^{19} m^3$ [6]
Volume of sphere with radius	V_a	$4/3 \times \pi r_a{}^3$	$4/3 \times \pi\, 6{,}372{,}770^3$	$108.411 \times 10^{19}\ m^3$
Geoid surface area	A_g	$4\,\pi\, r_g{}^2$	$4 \times \pi \times 6{,}371{,}000^2$	$510.064 \times 10^{12} m^2$
Surface area at alt. 1,770m	A_a	$4\,\pi\, r_a{}^2$	$4 \times \pi \times 6{,}372{,}770^2$	$510.347 \times 10^{12} m^2$

Atmospheric total mass	m_t	NA	NA	5.148×10^{18}kg [5]
Mass of air over 1m^2 at sea level	D_g	$m_t \div A_g$	$(5.148\times10^{18})/$ 510.064×10^{12}	10,093 kg
Atmospheric density @ alt. 6,300ft (1,770m)	d_a	NA	NA	1.00kg/m^3 [7,8,9]*
Atmospheric density @ sea level	d_{sl}	NA	NA	1.20 kg/m^3 [5,7]
Mean atmospheric density between sea level and alt. 1,700m	d_{m2}	$(d_{sl} + d_a) \div 2$	$(1.20 + 1.00) \div 2$	1.10 kg/m^3
Volume of air below alt. 1,770m	$V_{g\text{-}a}$	$V_a - V_g$	(108.411×10^{19}) – 108.321×10^{19}	9×10^{17} m^3
Mass of air below alt. 1,700m	m_2	$V_{g\text{-}a} \times d_{m2}$	$(9\times10^{17}) \times 1.10$	9.90×10^{17}kg
Mass of air above alt. 1,770m	m_1	$m_{t} - m_2$	5.148×10^{18} – 9.90×10^{17}	4.158×10^{18} m^3
Mass of air above 1m^2 at alt. 1,770m	D_a	$m_1 \div A_a$	$4.158\times10^{18}/$ 510.347×10^{12}	8,147 kg
Proportion of air mass above 1m^2 at sea level to that at alt. 1,770m	$D_{g:a}$	$D_g \div D_a$	10,093 ÷ 8,147	1.239
Increase in air mass above 1m^2 at sea level to that at 1,770m	$D_{g\text{-}a}$	$D_g - D_a$	10,093 – 8,147	1,946
Proportional increase in air mass above 1m^2 at sea level to that at 1,770m	D_{pi}	$D_{g\text{-}a} \div D_a$ or $D_{g:a} - 1$	1,946 ÷ 8,147 or 1.239 – 1	0.239
Height of iron used at alt. 1,770ft	I_a	Unknown	Unknown	2.5ft
Height of iron that should have been removed at sea level	I_{rc}	$I_a \times D_{pi}$	2.5ft × 0.239	0.597ft
Height of iron that should have been used at sea level	I_g	$I_a - I_{rc}$	2.5ft – 0.597	1.903ft
Height of iron used at sea level	I_{ge}	[1]	[1]	1.5ft
Height that was removed	I_r	[1]	[1]	1.0ft

* Although the pressure of air at differing altitudes varies with temperature and humidity, these variables are considered insignificant for the altitude concerned and degree of accuracy required, so nominal humidity and a temperature of 15ºC were assumed to determine a pressure, p of 83k-pa [8], at the altitude of 1,770m for application in the following equation [9] to determine density: - $p/0.2869(\text{temp.C} + 273.1) = 83/0.2869(15 + 273.1) = 1.00\text{kg/m}^3$. This value is approximately confirmed by the approx. value of 0.97kg/m^3 obtained by reference to a published graph [7].

There should be a more simple relationship supporting the above calculations. By logical deduction, the following principle emerges where inverse proportionality between iron and air applies when moving from one site to another so that the total slowing effect of both materials is maintained. This may be named 'The principle of inverse proportionality for elements restricting the speed of cosmic particles'.

Where the mass of air upon one unit of area is changed by a change in altitude from by the proportion *x*, the depth of additional material of uniform density required to bring cosmic particles of equal range of speeds to rest must be changed by *1/x*.

This principle may be expressed thus where the two altitudes are identified as A & B: -

$$\frac{\textbf{mass of air per unit area at altitude A}}{\textbf{mass of air per unit area at altitude B}} = \frac{\textbf{Height of additional matter at altitude B}}{\textbf{Height of additional matter at altitude A}}$$

That principle may now be tested. Given the air masses per square meter at sea level and altitude 1,770m, D_a and D_g; and the height of iron used at altitude, I_a and that which should have been used at sea level, I_g we get the following relationship and required height of iron: -

$$\frac{D_a}{D_g} = \frac{I_g}{I_a} \quad \therefore \quad I_g = \frac{D_a \times I_a}{D_g} = \frac{8147 \times 2.5}{10093} = 2.018 \text{ ft}$$

This differs from the calculation of 1.903 given in the table for the required height of iron at sea level by just 0.115ft or 6%, which may be attributed to minor errors in the data used and/or variations in the humidity of air from that used to calculate the given air densities. An average height of 1.96ft may therefore be considered very near the true height that should have been used.

Discrepancy

From the calculations conducted above using widely accepted data, the extent to which the experimenters miscalculated the height of iron required at sea level is established. As they stacked the iron to a height of 1.5 ft rather than the required 1.96ft, the shortfall of 0.46ft represented an error in relation to that which should have been applied of: - 0.46/1.96 × 100% = 23%. But as that height resulted from their calculation of what depth of iron should have been removed to represent the mass of air between sea level and 6,300ft, the true degree of error in calculation was the deviation of 0.46ft as a proportion of depth that was used; i.e.: -

0.46/1.0 × 100% = 46%

Reason For Discrepancy

The experimenters assumed that 1kg of iron and 1kg of air at sea level density have the same slowing down effect upon muons when contained in two vertical columns of equal base area, regardless of composition*. The density of air at sea level is approx. 1.2kg/m^3 [7], which when multiplied by 1,770m gives a mass of 2,124kgs for a 1m^2 column of air above the site at Cambridge, Massachusetts to the altitude of the site at Mount Washington. The density of iron is 7,850 kg/m^3, which when multiplied by a height of 1ft(0.305m) gives a mass of 2,394kgs above the same base surface area. Now although 2,394 differs slightly from 2,124kgs, it is clear the experimenters applied the same principle for calculating the height of iron. Had they used the mean density of all air below 1,770m, i.e. d_{m2} calculated to be 1.085kg/m^3 in the above table rather than density at sea level, a mass of 1920kg results, which, although more accurate should their assumption have been correct, would make the fundamental error less obvious, as it differs more from that derived from the removal of 1ft of iron. Although we are unaware of the true degree to which air of a given density slows muons, the experimenters could have ensured a valid result by maintaining inverse proportionality as proven by the calculations herein. If it were not for the deduced error, one may be tempted to imagine the experimenters reducing the height of iron by just the degree required for the count of muons to conform to predictions of time dilation by SRT. But it appears that their error resulted in a muon count that coincidentally supported the theory.

Conclusion

If the height of iron had been reduced by the correct proportion for use at sea level, more muons would have been stopped, resulting in fewer muons reaching the detector. The claim that muons would have been travelling within the range of speeds 0.9950c - 0.9954c for iron stacked to a height of 2½ft to almost stop them for capture by the less dense SLR immediately below is probably correct, but is of no consequence. The point of crucial importance was to ensure the proportions of heights of iron (relative to one another) were inversely proportional to the masses of air above the detector at each site and 'empty' space, so that observations were conducted upon batches of muons travelling within the same range of speeds and therefore representing equal intensities. Calculations provided herein prove that this proportion was incorrect by 23% and resulted from a miscalculation of 77%. The results were claimed to verify the validity of the 'Einstein Time Dilation' included in the Special Theory of Relativity to within an acceptable margin of error, therefore that experiment proved that theory to be invalid beyond any reasonable doubt given the degree of discrepancy.

In his conclusion at the end of the referenced film, Professor Frisch claimed the results proved the validity of SRT so that an observer travelling with a muon reaching sea level would cover the height of Mount Washington in just 0.7μ-sec according to his time reference rather than 6.3μ-sec's. Therefore, he would measure the altitude of Mount Washington as 700ft rather than 6,300ft in accordance with the Lorentz-Fitzgerald contraction, which must also be valid.

It was only at the Mount Washington site that the Professor described that the height of iron was calculated to bring muons to rest having been travelling at speeds 0.9950c - 0.9954c by stating "we know how far charged particles of a given mass can travel through matter", but without making reference to the mass of air above. If we assume that only 27 muons of the 658 batch observed would have reached sea level as predicted by decay times, this represents a survival rate of 1/21. If we assumed that is consistent for different speed ranges and multiply the observed number of 412 decaying at sea level by that proportion of 21, we arrive at 8,652 that would have been observed at 6,300ft for the same range of speeds. It may therefore be concluded that the intensity of muons increased by 8,652/568 or 412/27 = 15.2 fold for a batch of muons travelling at lesser speeds prior to observation at sea level, as they required less depth of iron to bring them to rest within the SLR.

In summary, all matter restricting the flow of muons should have been taken into account, but was not. By not considering the mass of air above the apparatus where used upon the mountain, the heights of iron used meant that the two batches of muons investigated were travelling at different ranges of speed, and the results, when interpreted correctly, proved: -

1. **Muons arrive at intensities that differ with speed.**
2. **The intensity of muons with a range of speeds 0.9950c - 0.9954c is less than that of those with an unknown range of lesser speeds.**
3. **The Special Theory of Relativity and the Lorenz-Fitzgerald contraction are disproved.**

References:

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* This video provides this introduction: -
In co-operation with The Commission On College Physics
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