Image Formation by Protons

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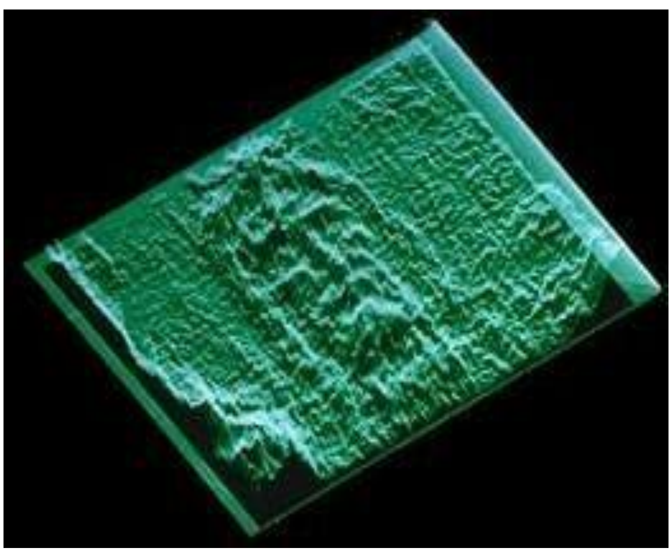
ABSTRACT The frontal and dorsal images of a man on the Shroud of Turin is unique. These images are believed to have been formed on the burial cloth of Christ when He was miraculously resurrected. No paint was used to create the images. The images reside on the top most fibers of the threads of the linen cloth. The image fibers are all the same color and intensity. The darker regions of the image are caused by a greater density of image fibers. The image fibers tend to lie adjacent to one another to produce striations. Results of calculations are presented that predict the decrease in energy of protons as they pass through air and linen fibers. These results suggest that proton radiation could have produced the Shroud images. Experiments were designed and performed in which linen was irradiated with high energy protons. The experimental results matched the calculated predictions. The predictions did not address the striations observed on the Shroud image threads; however, the striations were observed on the threads. The details of the mechanism for the image-forming process, such as the time duration of the process and the directions of the proton paths as they leave the surfaces of Christ's body are not addressed.

BACKGROUND: In 1976 John Jackson and Eric Jumper studied the image on the Shroud of Turin by using the VP-8 Image Analyzer[1] invented by Pete Schumacher. He said he never obtained any result like this with any photograph or any other image. His analyzer results are shown in Figure 1. These results indicate that the intensity of the image on the shroud is related to the distance between the shroud and the body of Jesus. Ordinary photographs analyzed with the VP-8 analyzer are not like the results obtained from the shroud; they produce distorted images that contained absolutely no distance information.



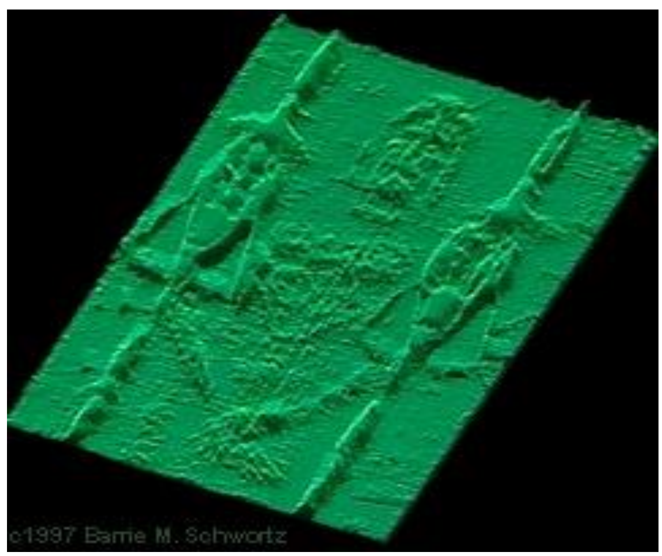


Figure 1. VP-8 Analyzer results for facial and upper torso images on the Shroud of Turin

In October of 1978 the Turin Research Project (STURP) composed of twenty-four investigators spent 120 continuous hours conducting examinations of the shroud[2]. During that time Mark Evans obtained thirty-two high resolution micrographs of various areas; two are shown in Figure 2a and 2b below. The linen was woven in a three-to-one herringbone twill pattern. To aid the reader in determining the magnifications of these two different images, the average thread diameter is about 0.026 centimeters. Notice that the image is caused by just a very few of the surface fibers on the threads having a darker color than their neighboring uncolored fibers; these darker fibers are denoted as image fibers.

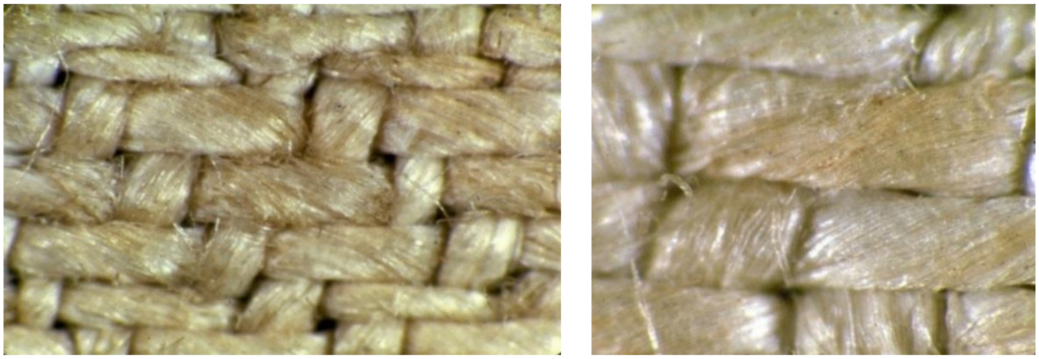
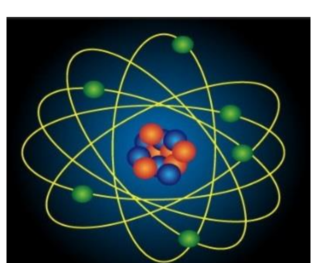


Figure 2a and 2b. Left image is from the foot area and right image is from nose area

Each thread contains between 70 and 120 flax fibers, and each fiber is about 13 micrometers (0.0005 inch) in diameter.[3] The two above micrographs along with comments from members of the STURP team and others reveal nine significant features of the shroud image that are relevant to this paper.

1. All of the image fibers are the same straw yellow color and intensity.
2. The image fibers are the top-most fibers on the threads.
3. Darker regions of image are caused by greater number of image fibers on the threads.
4. Where one image fiber crosses over another image fiber, there will be a white spot on the lower fiber.
5. The image fibers are colored only on the outer surface 0.2 micrometers (0.000008 inch) deep.
6. The color of the fibers was caused by the oxidation and dehydration of the cellulose of which the fibers are composed. No paint was found.
7. Even in the image areas very few fibers are image fibers, causing the image to be very faint.
8. The image fibers tend to lie adjacent to one another to produce striations, as described in the following. With reference to Figures 2a and 2b, the image fibers are top most on the threads and are a minority of the fibers on the threads. However, even though the image fibers are in the minority, they tend to lie in groups, side-by-side rather than being randomly located in the thread. Also, because the fibers were twisted when the thread was made, the image fibers are not aligned along the length of the thread, but appear to be tilted approximately 25 degrees. This along with just a few neighboring image fibers grouped adjacent to one another produces the striated appearance.
9. The image can be discerned by the naked eye best when viewed from large distances from the Shroud. [In 2000 the author found it very difficult to see the image when close to the shroud, but it was very obvious when seen from the rear of the Turin Cathedral.

In 1988 three linen samples were cut from a corner of the shroud near the foot and they were radiocarbon dated by three different laboratories. The calibrated calendar age range with 95% confidence was determined to be between 1260 and 1390 AD, about 1325 AD. At this point radiocarbon dating is briefly described by using Figure 3 which is a sketch of common carbon-12. Carbon-12 has 6 protons and 6 neutrons in in its nucleus that is surrounded by 6 electrons. Each proton has a unit of positive electrical charge and each electron has a unit of negative charge.



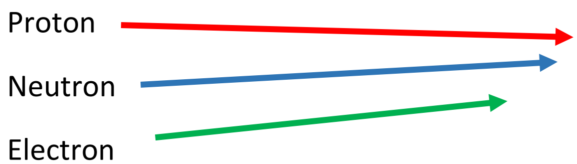


Figure 3 Schematic diagram of Carbon-12

Radiocarbon is carbon-14; it like carbon-12 has 6 protons, but it has 8 neutrons in its nucleus. Radiocarbon is constantly being formed in our upper atmosphere. Cosmic rays enter the earth's atmosphere in large numbers every day and they produce neutrons. These neutrons collide with nitrogen in our upper atmosphere. When the neutrons collide with a nitrogen-14 atom (seven protons, seven neutrons) it turns into a carbon-14 atom (six protons, eight neutrons) plus an ejected hydrogen atom (one proton, zero neutrons). The radiocarbon chemically combines with oxygen in the atmosphere to form carbon-14 dioxide, which is taken into living plants, just as carbon-12 dioxide is taken into plants. Cosmic ray activity varies from year to year, but on the average the ratio of carbon-14 to carbon-12 is 10^{-12} [0.000000000001]. Thus, in living plants this is the ratio carbon-14 to carbon-12. However, the half-life of carbon-14 is 5730 years, so in 5730 years this ratio decreases by a factor of two. Radiocarbon dating makes use of this fact to determine the age of plant materials, such as wood, plant fibers and bones of dead animals who have eaten plants.

Phillips[4] in 1989 proposed that the 1325 AD radiocarbon date of the shroud could be explained by neutron radiation that emanated from Christ's body during his resurrection interacting with a rare isotope of carbon in the linen to cause its radiocarbon age to appear much younger than actual. Hedges in 1989 pointed out that linen contains nitrogen and that neutron collisions with nitrogen in linen would be a more probable reaction; this is the same reaction that makes the radiocarbon in our upper atmosphere. Rinaudo[5] in 1998 proposed that if during Christ's resurrection neutrons were emitted, then it is likely that protons might also have been emitted from Christ's body to produce the image. To support his image forming proposal, in 1999 Rinaudo conducted experiments in which he irradiated linen with protons having an energy of with 1.4 Mev. A photograph of -Rinaudo's result is shown in Figure 3 where it is compared with Mark Evans' photo of the shroud in the area of the foot.

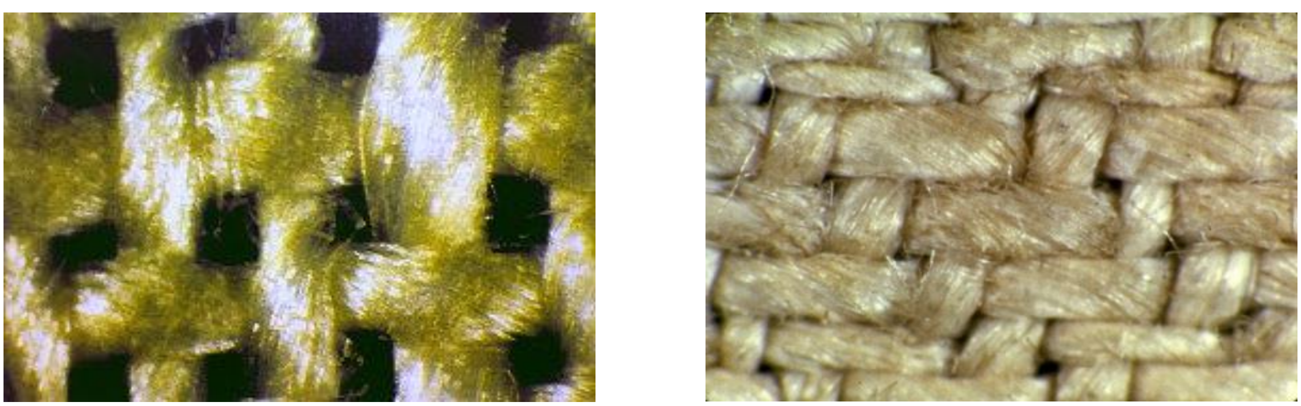


Figure 4. Rinaudo's proton irradiated linen compared with Marc Evans micrograph of the foot area

Unfortunately, Rinaudo did not use linen that simulated the shroud linen and the illumination that he used when photographing his linen produces severe reflections, so it is difficult to make a fair comparison. His photographs did not demonstrate that only a few of the top most fibers were colored. Instead, they do show that virtually all surface fibers are colored, which is not what is observed on the image fibers of the shroud. Also, Rinaudo's results show no signs of striations that were observed on the shroud image fibers. However, Rinaudo did performed three physical and chemical tests whose results agreed with observations of shroud image fibers. These tests and their results are enumerated below.

1. The image fibers were on the surface of the threads. [However, Rinaudo's photos showed that three or more layers of image fibers laid below the top most fibers. This is addressed in the Calculations section of this paper.]
2. Only the outer surface of the image fibers was colored as verified by the color instantly disappearing when his colored fibers were subjected to a reducing agent; this had been observed by Heller and Adler on shroud image fibers[6].
3. The image fibers did not fluoresce when illuminated with ultraviolet, as was observed during the STURP examinations of the shroud [non-image linen fibers are naturally fluorescent].

These three findings convinced Rinaudo that protons were released from Christ's body during the resurrection to produce the image on the shroud.

GOAL OF THIS RESEARCH: Determine if proton irradiation of linen can duplicate all the reported observations of the image areas on the Shroud of Turin. In particular determine the energy and density of the proton irradiation to duplicate the striations observed on the shroud image.

CALCULATIONS: Calculations were made to determine the energy of protons needed to penetrate only the top most linen fibers, as had been observed on the shroud. The details of the calculations are not presented in this paper most readers will not want nor need to see them. Therefore, this paper will only present the results of the calculations.

When a proton enters a material, it interacts with the atoms in the material causing it to lose energy. Below is a graph that shows the energy of protons with different initial energies as they pass through linen.

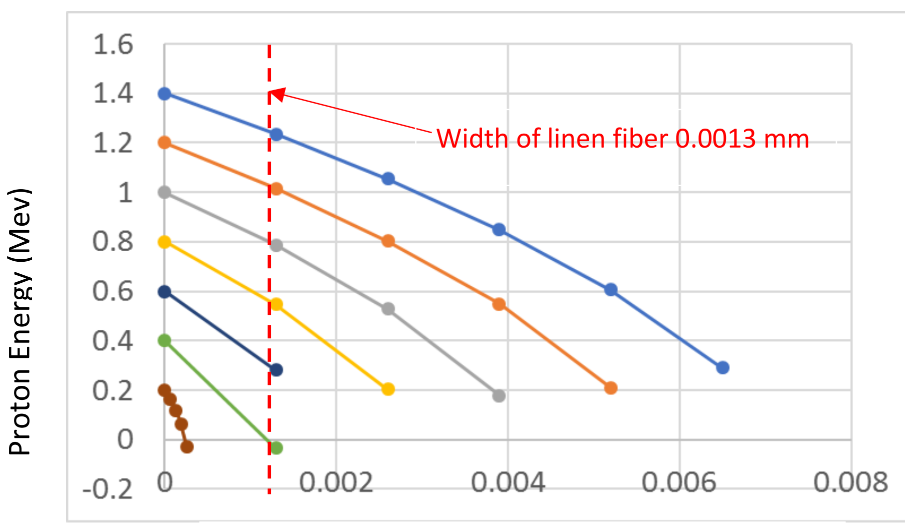


Figure 5. Decline of proton energy in linen

Because the shroud image only exists on the upper-most linen fibers that are 0.0013 mm in diameter, a vertical dotted red line is drawn in the above graph at a thickness of 0.0013 mm. It can be seen that the 1.4 Mev proton that Rinaudo used will penetrate more than six linen fibers and this was revealed in Rinaudo's additional photos that showed that many underlying fibers were discolored. This graph also indicates that a 0.4 Mev proton will penetrate just one fiber. Thus, the proton energy when it hit the Shroud linen must have had an energy less than 0.4 Mev. Since the shroud is most probably in contact with Christ's body at many locations, this means that the proton energy as it leaves Christ's body cannot exceed 0.4 Mev.

Below is a graph that shows the energy of protons with different initial energies as they pass from Christ's body through air to the shroud.

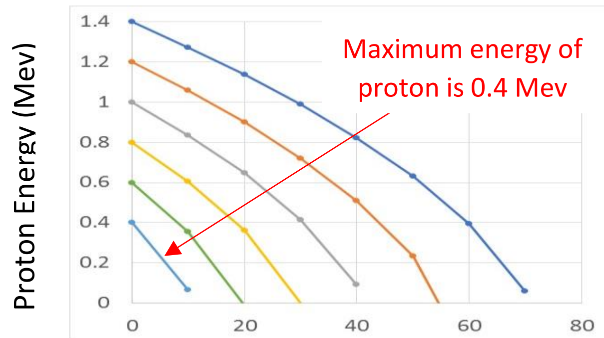


Figure 6. Decline of proton energy in air

This graph shows that because the proton energy cannot exceed 0.4 Mev, the proton will lose all its energy when passing only 11.7 cm (4.6 inches) in air. Thus, those parts of Christ's body that are greater than 11.7 cm away from the shroud will not produce an image on the shroud. This is confirmed in the image in Figure 7. The area to the right of the crossed hands shows no body image. This is consitent with actual measurements made of a cloth draped over the crossed hands of a prone adult man that indicate that the distance between the cloth and the body is about 4.6 inches in the area adjacent to the crossed hands. Likewise, the measurement of the distance from the tip of the nose back to the ear is greater than 4.6 inches, so this explains the absence of ear images and also the narrow face in the shroud image.

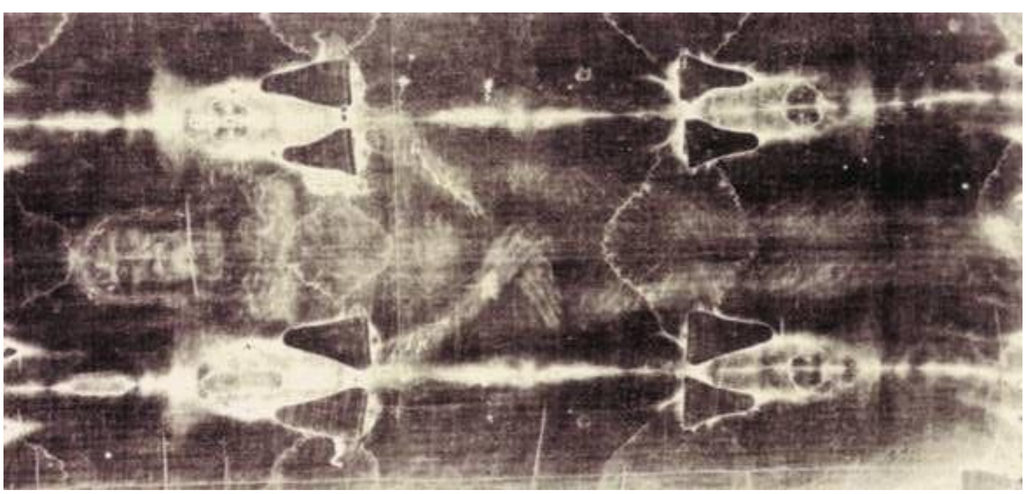


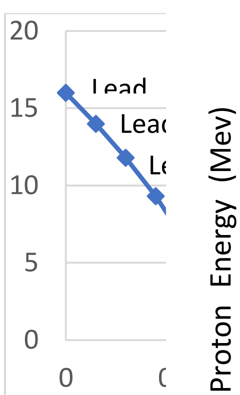
Figure 7. Shroud image

DESCRIPTION OF EXPERIMENTS: Modern linen whose properties were very similar to the Shroud linen was irradiated with protons to determine if the results duplicated what has been observed on the Shroud image fibers. First it was necessary to obtain linen having properties similar to the Shroud linen. Giulio Fante (Professor at the University of Padua, Italy) had previously found that a linen sold by an online German fabric store[7] matched the density of the Shroud linen, so this linen was used in these experiments. The properties of the Shroud linen and the German linen are compared in the table below.

Linen	Density (grams/cm^2)	Weft (threads/cm)	Warp (threads/cm)
Shroud	22.9 to 23.7	26	38.6
German	25 to 25.6	13	15

It is seen that the densities are very similar, but the Shroud linen has threads that are much finer and more tightly packed together. Also, the Shroud has a herringbone weave, but the German linen is a plain weave. These differences are not important in this study as both used flax to make the thread. However, all modern threads are sized used to reduce breakage of the yarn during weaving. Different types of water soluble polymers called textile sizing agents/chemicals are used, such as modified starch, polyvinyl alcohol, carboxymethyl cellulose; thus, the German linen was washed and rinsed two times before using. The German linen was stiff before washing and soft after washing, indicating all sizing was washed off.

The results of the calculations presented above indicate that the proton energy when it enters the linen should be 0.4 Mev. However, most cyclotrons today produce protons that have energies 100 or many times larger. The proton source that was used in this experiment produced protons whose energy was 16 Mev. To reduce the energy of 16 Mev protons down to 0.4 Mev required that the velocity of the proton be slowed down by having it pass through several layers of materials. This required several calculations to determine what available materials should be used and what their thicknesses should be. The plot below shows the calculated proton energy decline as a proton passes through 4 layers of 0.0127 cm thick pure lead sheets and 5 layers of German linen.



Distance (cm)

The calculations indicated that the proton energy would be 0.26 Mev as it exited the 5th layer of linen. The calculations were exact, but the linen was not a precisely made material, so this added an uncertainty. The experiment was originally planned to use 6 layers of linen, but the setup at the cyclotron did not accommodate more than five polymer layers. Calculations were made for several different combinations of different metal foils, polymer foils followed by five linen layers within the thickness constraint, but the above configuration was found to produce protons whose energy was close to but not greater than 0.4 Mev as they exited the fifth layer of linen. Below is a picture of a linen sample that was used; it consists of four layers of linen (4.5 cm x 3.5 cm). On top of the linen are the 4 layers of 0.0127 cm thick pure lead foils that were used to significantly reduce the energy of the 16 Mev protons. The energy of the protons was further reduced as they passed through several layers of linen so that the energy became close to 0.4 Mev, the calculated maximum energy of the protons as they left Christ's body.

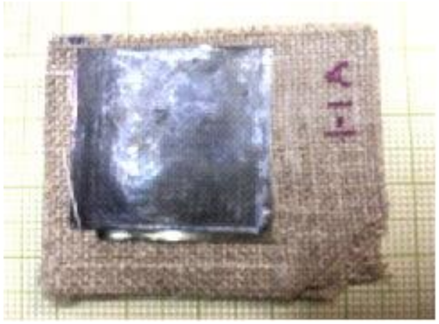


Figure 8. Four lead foils on top of five linen samples. (1-centimeter graph paper for scale reference.)

After proton irradiation no image was visible on the linen because while the protons break chemical bonds the image is the result of the slow oxidation and dehydration reactions that follow[6]. To speed such reactions, it is common to heat the sample at 150 Celsius for 10 hours; this procedure produces results in 10 hours that would take 9.4 years at room temperature. Thus, if proton irradiation produced the image on the Shroud, no image would have been seen on the Shroud until much time had passed.

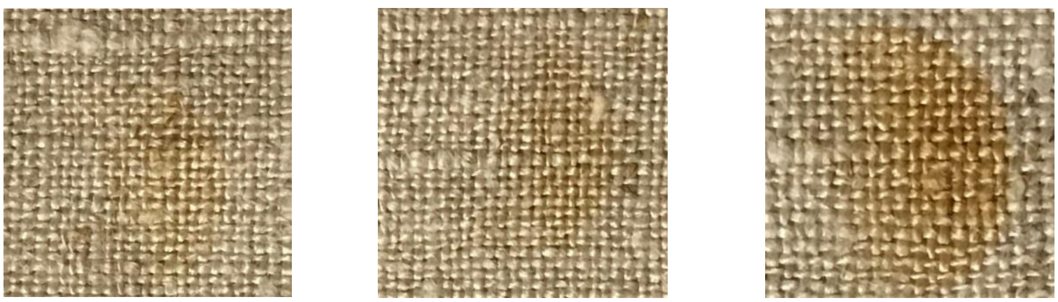


Figure 9. Back of linen #4 (slight image), front of linen #5 (slight image) and back of linen #5 (intense image)

An enlarged view of the right-hand image of Figure 9 is shown below in Figure 10. The striations seen on the image fibers of the Shroud can be seen at right hand edge of the beam where the proton density decreases.

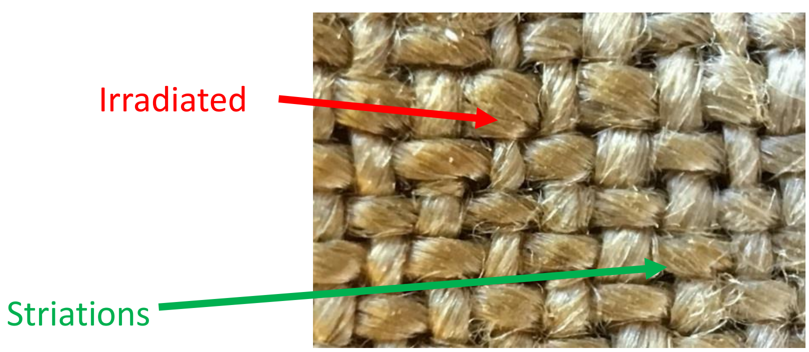


Figure 10. Back of linen #5 at edge of proton beam where proton energy and density decreased.

Below in Figure 11 the striations seen on the Shroud are compared with the striations seen in proton irradiated linen. The proton energy and density must be just right to produce the striations.

Figure 11. Comparison of Shroud image near foot (left) and proton irradiated modern linen (right). At the edge of proton beam where density of protons declines, it matches the character of what is seen on the Shroud. The Shroud image has a much higher magnification.

Some unique features of the image fibers on the Shroud are also seen in the proton-irradiated linen. When evaluating this statement, it must be realized that the linens are not identical and that the lighting and color sensitivity of the photographic processes are not identical.

1. All image fibers have the same color; however, the intensity of the image is governed by the number density of the image fibers.
2. In the proton irradiated image, at the edge of the proton beam, where the number density of protons declines, the image fibers tend to lie adjacent to one another to produce striations; this is also seen on the Shroud fibers.

CONCLUSIONS: Proton irradiation of linen can produce results that match the properties of the image of the image on the Shroud of Turin. In particular, the image lies of the top most fibers of the threads and striations are produced, just as observed on the Shroud. While the calculations of proton energy decline as they pass through lead and linen agreed with observations, this research did not answer the question of why the image fibers are not uniformly distributed on the surface of the threads, but instead the image fibers tend to group together leaving many surface fibers uncolored. This produces the striations observed on the Shroud threads and also on the threads of the linen used in this research. A possible explanation for the striations may be the nature of the linen threads that are made from fibers obtained from flax plants. It may be possible that a single thread may contain fibers from different parts of the flax stem or even from stems of different flax plants. Thus, differences in their composition may produce different results when they are proton irradiated.

APPENDIX: This appendix describes the method used for computing the proton energy after it passes through lead and linen. These calculations require the measured stopping powers (SP) for the elements lead, hydrogen, carbon, and oxygen as a function of proton energy[8]. As an example, if it is desired to know the energy a 16 Mev (Mev = million electron volts) proton would lose in passing through a 0.05 cm thick layer of lead [density 11.4 gm/cm^3, the following calculation would be used, where the stopping power if lead at 16 Mev is 13.38 Mev·cm^2/g

Energy lost=StoppingPower x Density x Distance

Energy lost = 13.38 Mev·cm^2/gm x 11.4 gm/cm^3 x 0.05 cm

Energy lost = 7.6266 Mev

Energy after passing through lead = 16 Mev – 7.6266 Mev = 8.3734 Mev

However, the stopping power increases as the proton energy decreases, so the above result underestimates the energy lost in a sample. Proper calculations of proton energy loss need to take this into account. The correct energy after passing through the lead is 6.6286 Mev. The errors grow larger for thicker layers of material. Even when the material is broken into a manageable number of thin layers, the calculations the are inadequate for accurately computing proton energy lost. The author has found that tabular data of stopping powers for proton energies from 1 to 20 Mev (million electron volts) for elements and compounds of interest in this work for can be expressed as $SP(E)=A \cdot E^{-\alpha}$, where each material has its own values for A and α. A and α for each material can be obtained by taking the tabular data and plotting Log(SP(E)) as a function of the Log(E). By plotting the logarithms of these, it was found that the result is a straight line and can be represented by the equation below.

$$\text{Log}[SP(E)] = \text{Log}(A) - \alpha\, \text{Log}(E) \quad (1)$$

Thus, the plot of Log[SP(E)] versus Log(E) using the tabular data turns out to be a straight line over the range of E=1 Mev to E=20 Mev, the range of interest here. The intercept at E=1 Mev is equal to Log(A), which determines A and the slope of the line is equal to -α. Thus, A and α are easily determined from tabular data for both elements and compounds where tabular data is available[8].

Each material has different a value for A, α and ρ and the calculated values for lead and linen that were used in this work are listed below.

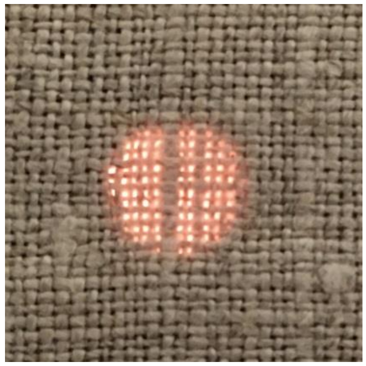
Lead: A=68.138 α=0.587 ρ=11.4

German Linen: A=164.2 x 0.71 α=0.7749 ρ=0.632 (obtained by adding stopping powers of C, H and O in linen)

Because Lead and German Linen have the above known values for A, α and ρ, it was possible to develop an analytical expression that properly accounts for the increase in stopping power as the protons lose energy when propagating through thick sheets of Lead and German Linen. Thus, a proton having an initial of energy E_0 after passing through any distance x, d, of a sheet of material having the known values of A and α will have an energy $E_f(x)$ given by

$$E_f(x)= [E_0^{\alpha+1} - A\cdot\rho\cdot x\cdot((\alpha+1)]^{1/(\alpha+1)]} \quad (2)$$

The above equation provided results that were in agreement with experimental results for solid materials, such as lead, tin and polyethylene. However, even though the stopping powers of the carbon, hydrogen and oxygen in the linen were correctly incorporated in the calculations, the calculations yielded a proton energy, E_f, that appeared to be consistently 29% lower than was observed in the experimental results. The calculated value of A=164.2 for linen did not agree with experimental results, but when it was multiplied by 0.71 (29% less) the calculated results did agree with experimental measurements. A photograph of the German linen used in these experiments, shown below, explains the cause of this discrepancy. This photograph was taken in normal room light, but the linen was also illuminated with a spot light from below.



The above photograph shows that the linen has noticeable nearly square-shaped gaps between the threads. Thus, when protons passed through these gaps no reduction in their energy was caused by the linen. If all threads were rectangular in cross section, the open area would be 25% of the total area, so no reduction in energy would occur for protons that passed through the gaps. Thus, the energy reduction would be about 100%-25%, or 75% of the calculated energy. Naturally, the gaps in the many layers of linen that were used would not all line up, so on average all protons would experience a 75% reduction in energy. The measured reduction in energy was 29%, less than the expected 25%; this can be explained by the fact that the threads are not square, but more nearly circular in cross section. Therefore, the parameter A in equation (2) was multiplied by 0.71 (1-0.29) for German linen calculations. This resulted in excellent agreement with experimental results.

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