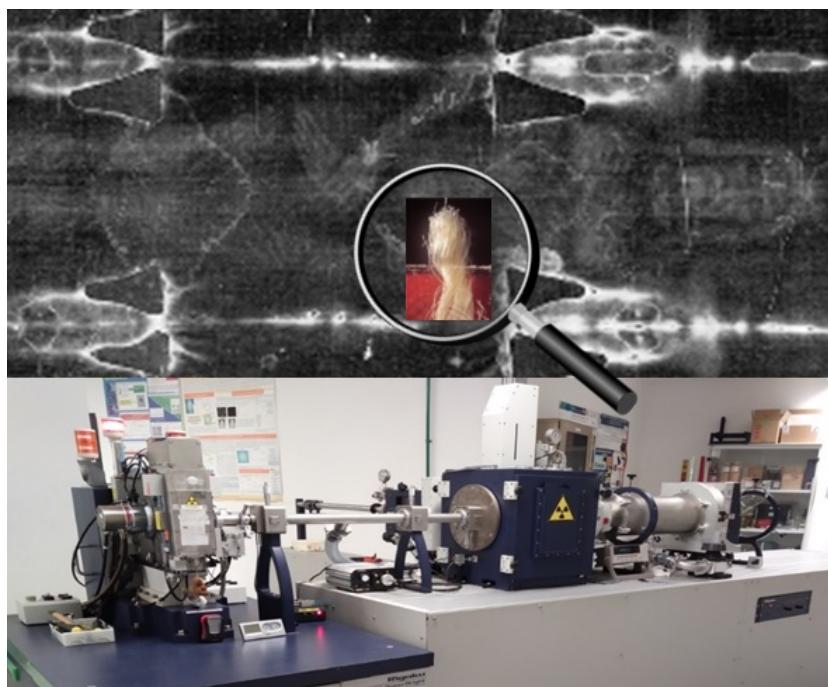


## X-ray dating



On a sample of the Turin Shroud (TS), we applied a new method for dating ancient linen threads by inspecting their structural degradation by means of Wide-Angle X-ray Scattering (WAXS).

The X-ray dating method was applied to a sample of the TS consisting of a thread taken in proximity of the 1988/radiocarbon area (corner of the TS corresponding to the feet area of the frontal image, near the so-called Raes sample). The size of the linen sample was about 0.5 mm  $\times$  1 mm. We obtained one-dimensional integrated WAXS data profiles for the TS sample, which were fully compatible with the analogous measurements obtained on a linen sample whose dating, according to historical records, is 55–74 AD, Siege of Masada (Israel). The degree of natural aging of the cellulose that constitutes the linen of the investigated sample, obtained by X-ray analysis, showed that the TS fabric is much older than the seven centuries proposed by the 1988 radiocarbon dating.

The experimental results are compatible with the hypothesis that the TS is a 2000-year-old relic, as supposed by Christian tradition, under the condition that it was kept at suitable levels of average secular temperature—20.0–22.5 °C—and correlated relative humidity—75–55%—for 13 centuries of unknown history, in addition to the seven centuries of known history in Europe. To make the present result compatible with that of the 1988 radiocarbon test, the TS should have been conserved during its hypothetical seven centuries of life at a secular room temperature very close to the maximum values registered on the earth.

Reference: <https://www.mdpi.com/2571-9408/5/2/47>

#### Reference works

- [1] P. E. Damon et al., *Radio carbon dating of the Shroud of Turin*, Nature 337, (1989), pp. 611–615.
- [2] B. Walsh, L. Schwalbe, *An instructive inter-laboratory comparison: The 1988 radiocarbon dating of the Shroud of Turin*, J. Archaeological Science: Reports 29 (2020), 102015ss.
- [3] L. De Caro, C. Giannini, R. Lassandro, F. Scattarella, T. Sibillano, E. Matricciani, G. Fanti, *X-Ray Dating of Ancient Linen Fabrics*, Heritage 2 (2019), pp. 2763-2783.
- [4] L. De Caro, T. Sibillano, R. Lassandro, C. Giannini, G. Fanti, *X-ray Dating of a Turin Shroud's Linen Sample*, Heritage 5 (2022), pp. 860-870.
- [5] <https://www.mdpi.com/2571-9408/5/2/47>

On April 11, 2022, the journal *Heritage* published a study by CNR (National Research Council of Italy) scientists, including [Giulio Fanti](#), using Wide-Angle X-ray Scattering (WAXS) to date a Shroud of Turin sample, suggesting it's about 2,000 years old, contradicting the 1988 C-14 dating by showing natural cellulose aging consistent with much older linen, like that from Masada. This research, led by [Liberato De Caro](#), found the linen's aging level was far greater than 700 years, aligning with antiquity and supporting the Shroud's authenticity, though other studies suggest medieval creation through different means like sculpture or lasers.

#### Key Points of the CNR Study:

- **Methodology:** [Wide-Angle X-ray Scattering](#) (WAXS) measures the natural breakdown **(depolymerization) of cellulose fibers over time.**
- **Findings:** The sample's aging level matched linen from the 1st century AD (Masada, Israel), indicating the Shroud is much older than the medieval period suggested by the 1988 radiocarbon dating.
- **Authors:** Liberato De Caro, [Teresa Sibillano](#), [Rocco Lassandro](#), [Cinzia Giannini](#), and Giulio Fanti.
- **Publication:** "X-Ray Dating of a Turin Shroud's Linen Sample" in *Heritage* (April 11, 2022).

#### Context & Counterarguments:

- **1988 Radiocarbon Dating:** Suggested the Shroud dated to 1260–1390 AD.
- **Criticism of 1988 Study:** Some argue a medieval fire or contamination could have skewed results, while others defend its accuracy.
- **Other Theories:** Some research suggests the image might have formed via contact with a sculpture or intense light (like a laser), pointing to a medieval artistic origin.

In essence, the CNR/Fanti study presented a new X-ray dating technique that challenged the medieval dating, suggesting an antiquity of 2,000 years, adding complexity to the ongoing scientific debate about the Shroud's origin

Depolymerization of flax fibers, primarily cellulose, involves breaking down its long chains using methods like heat, supercritical

CO<sub>2</sub>CO sub 2CO<sub>2</sub>

, or enzymes (like cellulases/ligninases) to extract [cellulose nanocrystals](#) (CNCs) or modify the fiber for better composite performance, often targeting the lignin and hemicellulose matrix to enhance cellulose isolation or improve interface with polymers, with enzymatic or chemical treatments offering greener routes to high-purity cellulose