The Sudbury Neutrino Observatory

Trapping Elusive Particles Sent by the Sun

Deep in a mine in northern Ontario, Canada, the Sudbury Neutrino Observatory (SNO) counts tiny particles emitted in abundance by the Sun. Billions of them are passing through your thumbnail right now! Miniscule and inconspicuous, these neutrinos have less than one chance in a trillion of being stopped by the entire mass of our planet.

Still, using a 1000-tonne heavy water neutrino trap, SNO is able to catch a few solar neutrinos per day.

The experiment has been a resounding success, resolving a decades-old mystery about the inner workings of the Sun.

Aerial View of Inco's Creighton Mine
Sudbury, Ontario, Canada
The above-ground facilities of the Sudbury Neutrino Observatory are nearby, but the detector is two kilometres below ground.

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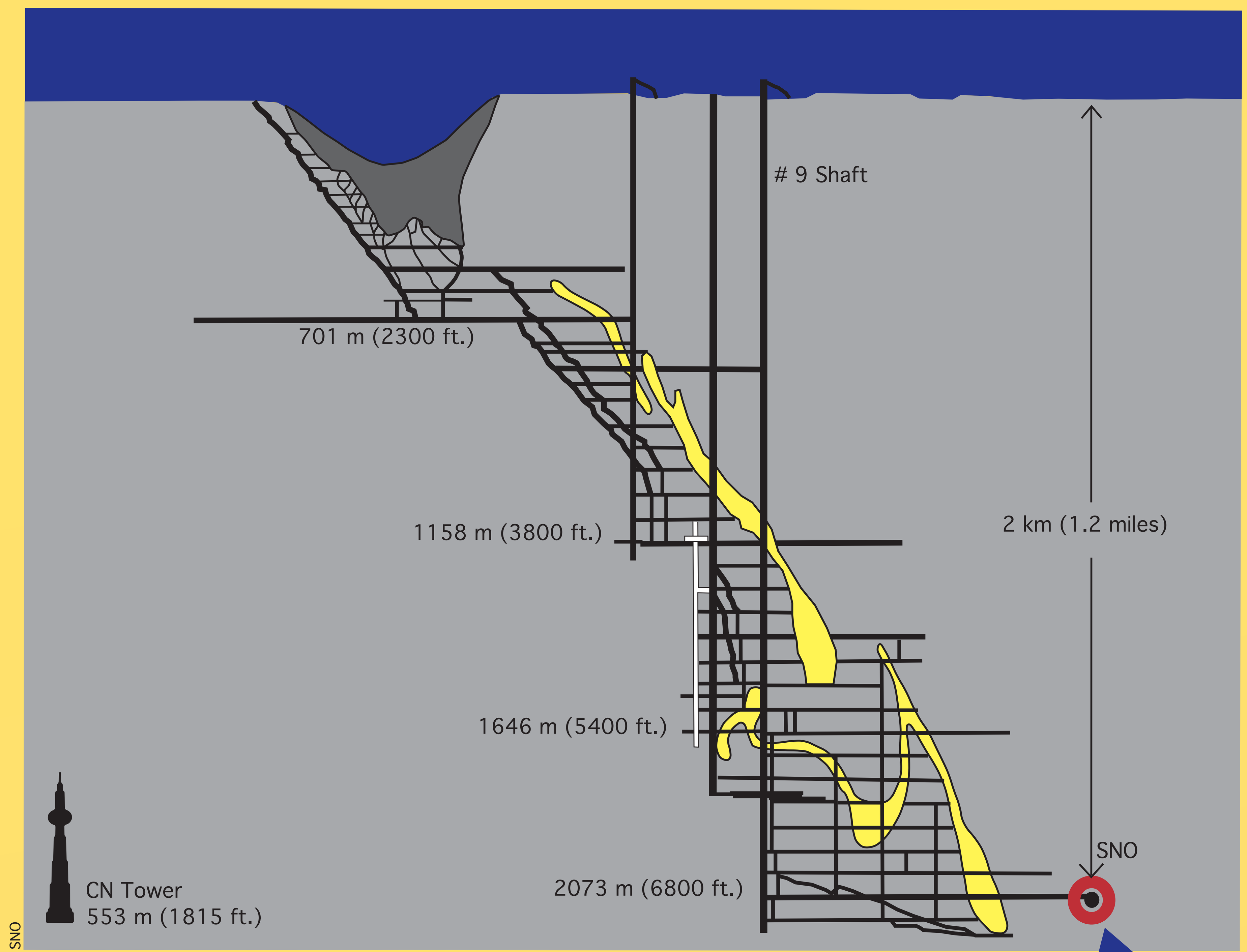
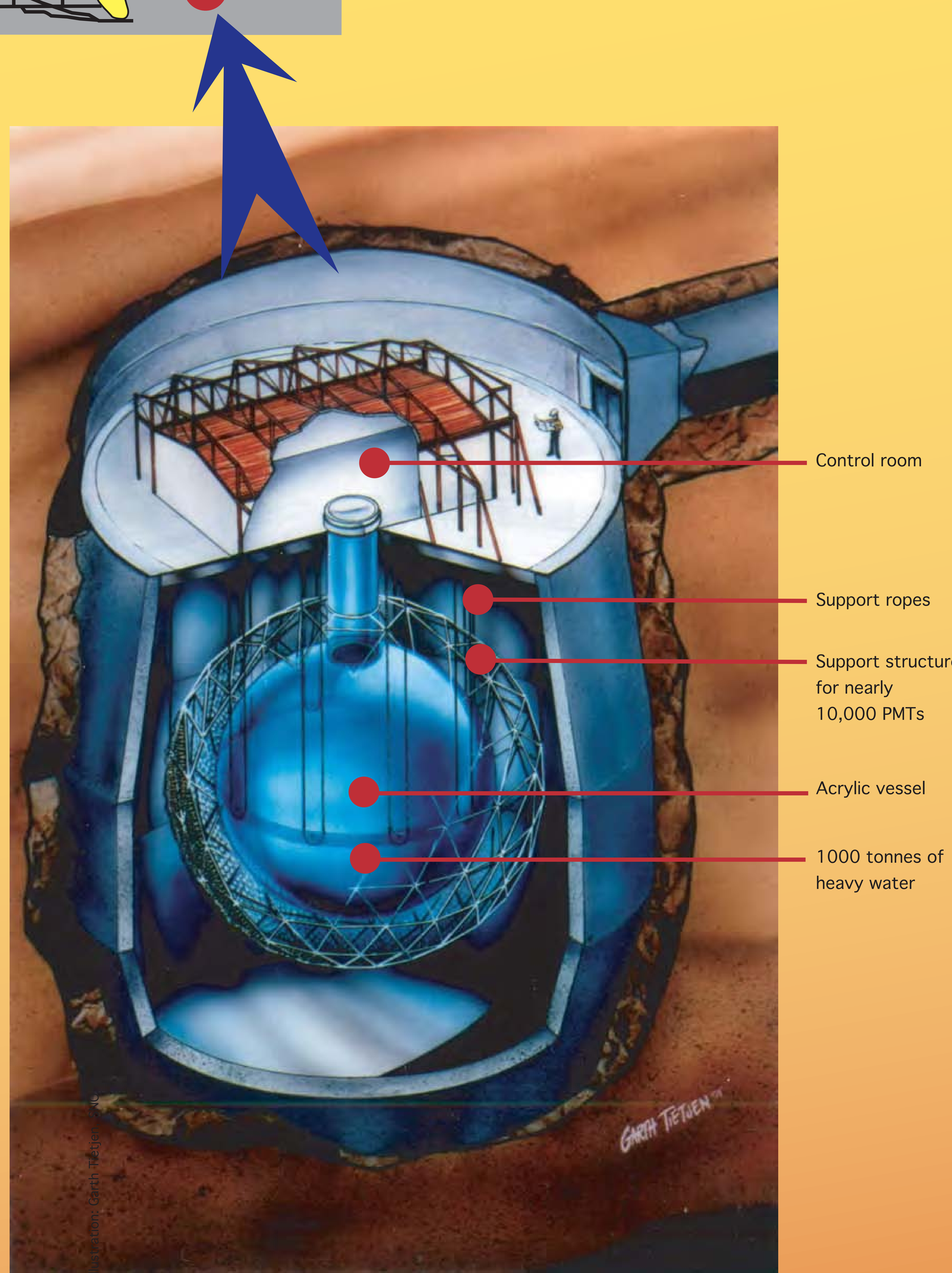
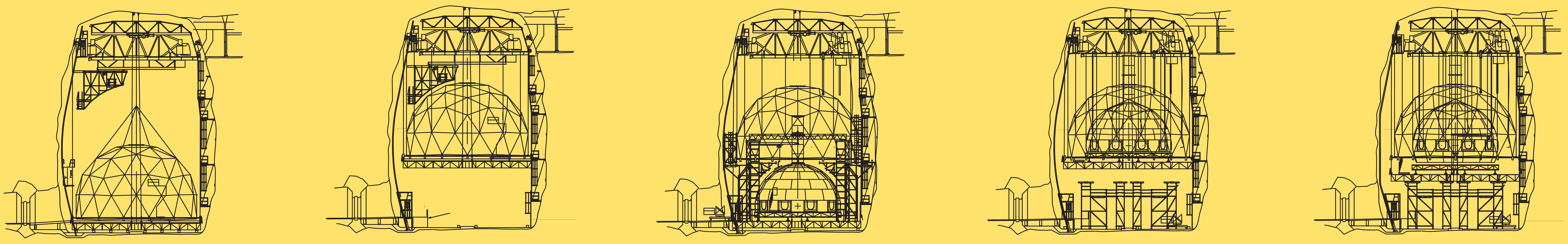


Profile of Inco's Creighton mine, showing the location of SNO

Artist's concept of the SNO detector, showing the acrylic vessel and supporting structures and facilities





What is the function of the Sudbury Neutrino Observatory?

A

To study sunspots and solar flares?

B

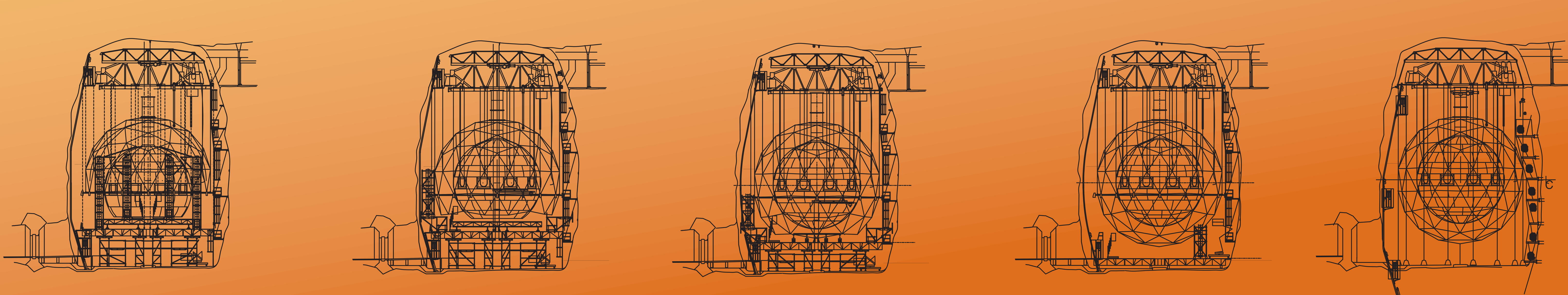
To count the hard-to-catch particles produced deep within the Sun?

C

To investigate the atomic structure of radioactive substances?

ANSWER:

B) To count the hard-to-catch particles produced deep within the Sun.



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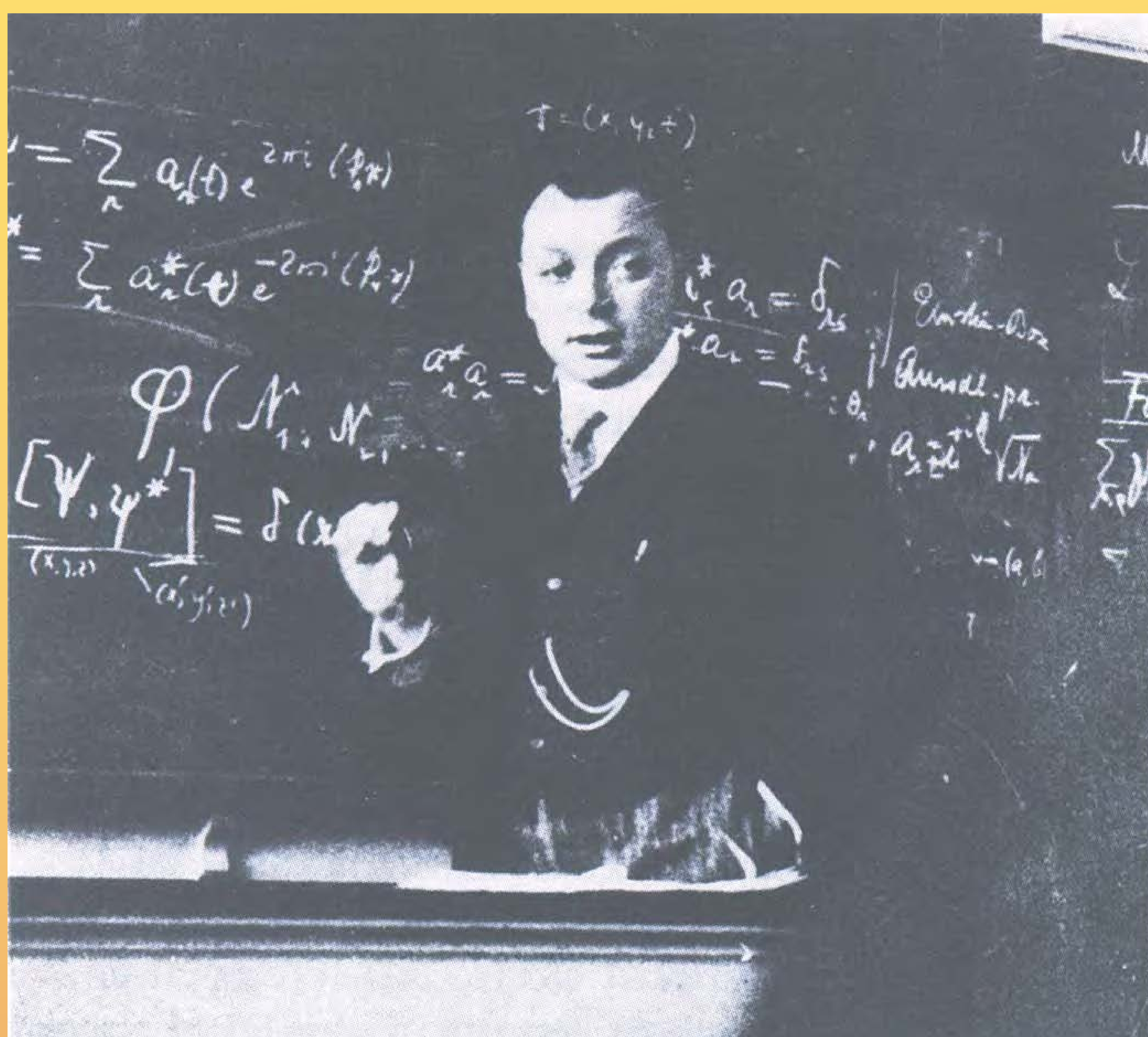
Why we did the experiment

The Neutrino Story

In 1930, in order to solve a baffling physics problem of disappearing energy, Wolfgang Pauli predicted an invisible particle: the “neutrino”. By the 1960s, physicists were able to use computers to calculate how many neutrinos might be generated by the Sun’s energy-producing processes. But measuring these particles was extremely difficult, because they pass right through the Earth, rarely interacting with a single atom.

> “ I have done something very bad today by proposing a particle that cannot be detected; it is something no theorist should ever do.”
>
> — Wolfgang Pauli (1932)



Wolfgang Pauli 1900–1958
In 1930, Wolfgang Pauli first conceived of neutrinos—originally as a solution to a problem in nuclear physics. Neutrinos are so elusive that it would be 26 years before they were actually detected.

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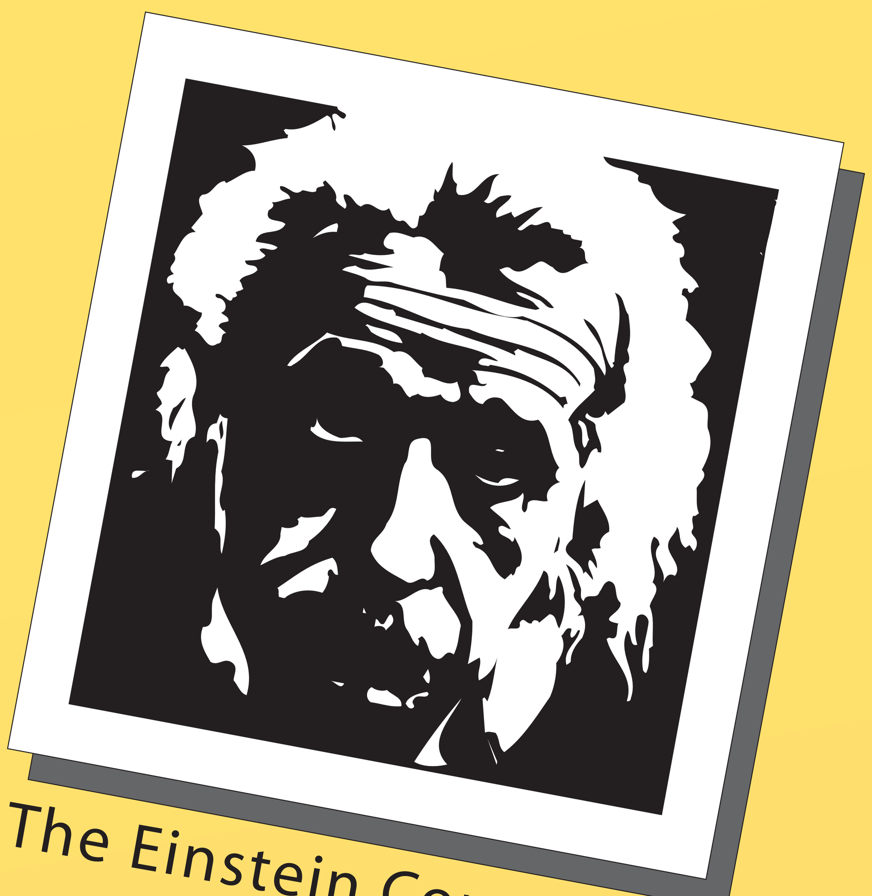
How the Sun Shines

Special Relativity and $E=mc^2$

(Energy equals mass times the speed of light squared)

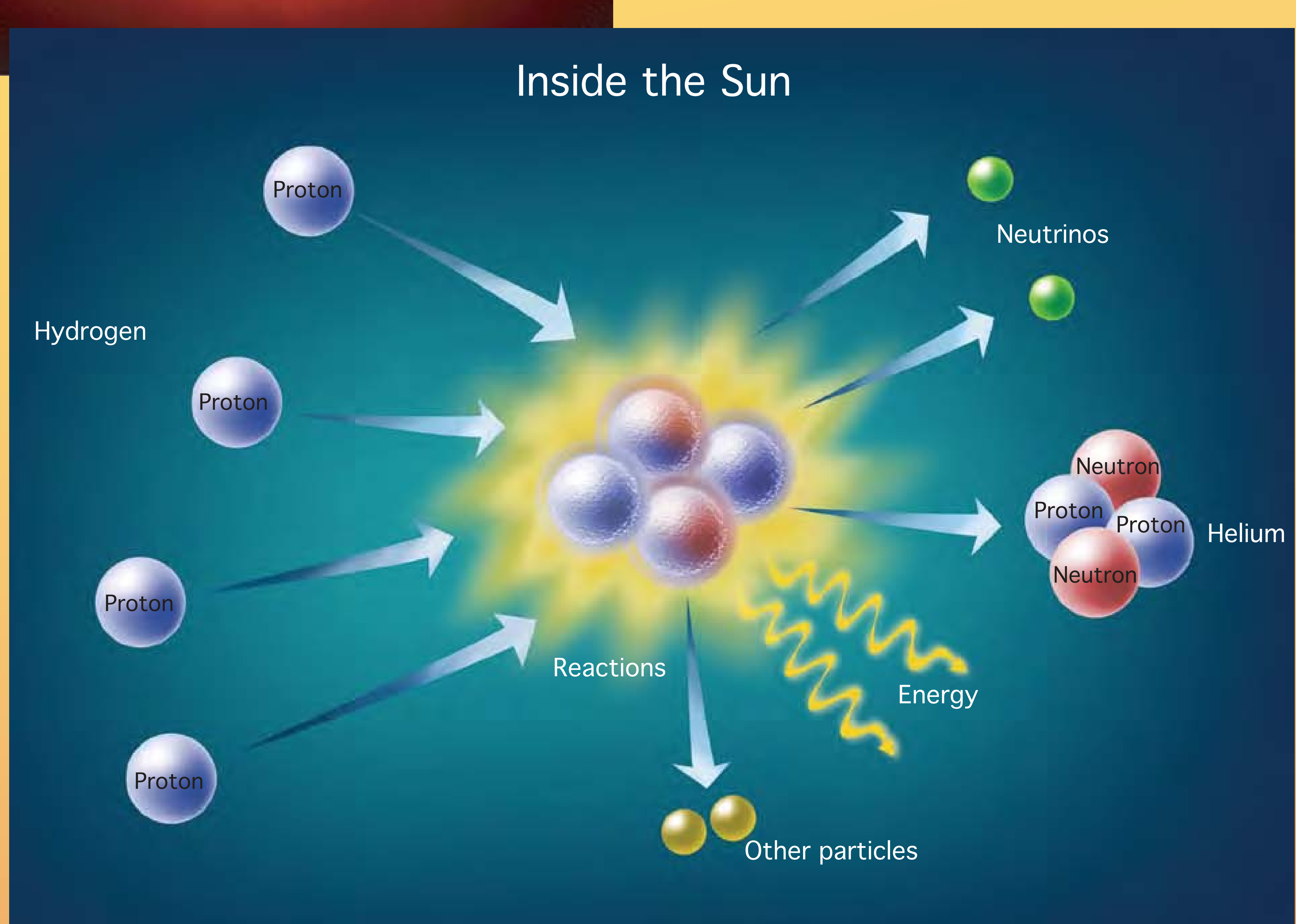
In 1905, as Einstein contemplated how the laws of physics governing light and motion would change at high speed, he came to a startling conclusion: matter and energy must be different aspects of the same thing!

Deep in the Sun's core, four hydrogen atoms fuse into one helium atom, which is lighter than all four original hydrogen atoms combined. That extra mass is converted to energy and eventually released into space as rays of light.



The Einstein Connection

Activity on the surface of the Sun is an indirect indicator of activity in its core. Neutrinos provide a direct link to the Sun's nuclear powerhouse, and provide a way of checking theories about the reactions that heat the Sun—and us here on Earth.



When hydrogen fuses into helium, it releases energy and tiny neutrinos. Scientists originally predicted that, in any given second, about 5.1 million high energy solar neutrinos are passing through each square centimetre of Earth's surface.

The Missing Solar Neutrinos

A Longstanding Mystery

In 1968, when scientist Raymond Davis, Jr. began to count solar neutrinos, he found only one-third the expected number.

Did that mean scientists didn't understand the Sun? Or did Davis make a mistake?

This problem puzzled physicists for over thirty years.

Raymond Davis Jr., 1999

In 1968, Raymond Davis was the first to successfully detect neutrinos from the Sun. He used this tank, 6 metres (20 feet) in diameter and 15 metres (48 feet) long, underground in the Homestake mine, South Dakota. The tank held 400,000 litres (100,000 gallons) of dry-cleaning fluid (perchloroethylene).

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Neapolitan Neutrinos

Chocolate, Strawberry and Vanilla

Since the 1970s, scientists have been convinced that neutrinos can have three different “flavours”: electron-neutrino, muon-neutrino and tau-neutrino. They also suspected that neutrinos might be able to switch between flavours. The Sun produces only electron-neutrinos or “vanilla” neutrinos.

Davis’s experiment was designed to identify these vanilla neutrinos. Did his experiment count too few of them because neutrinos change flavour on their way from the Sun to the Earth? Did the chocolate and strawberry ones just pass through undetected?