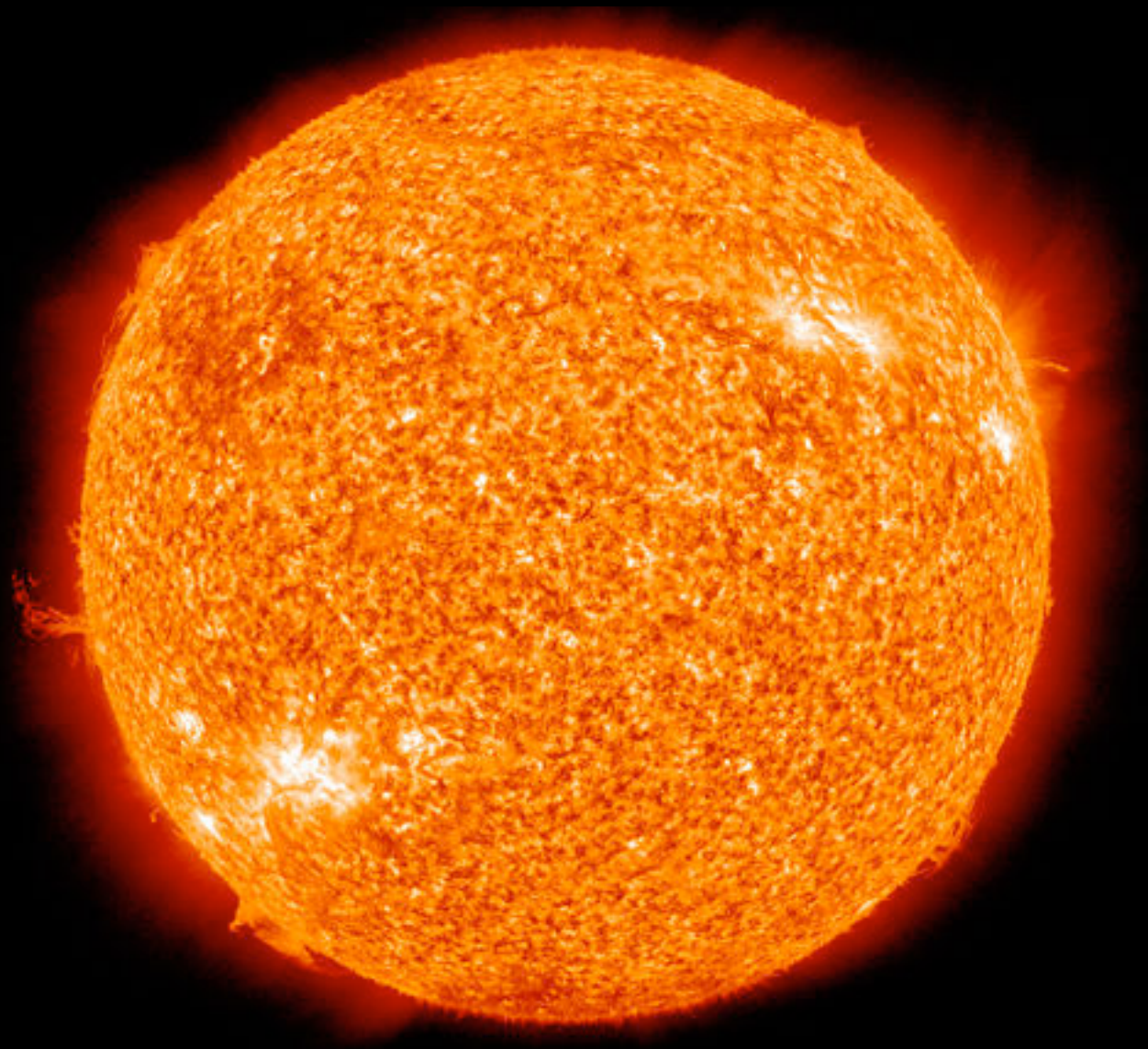
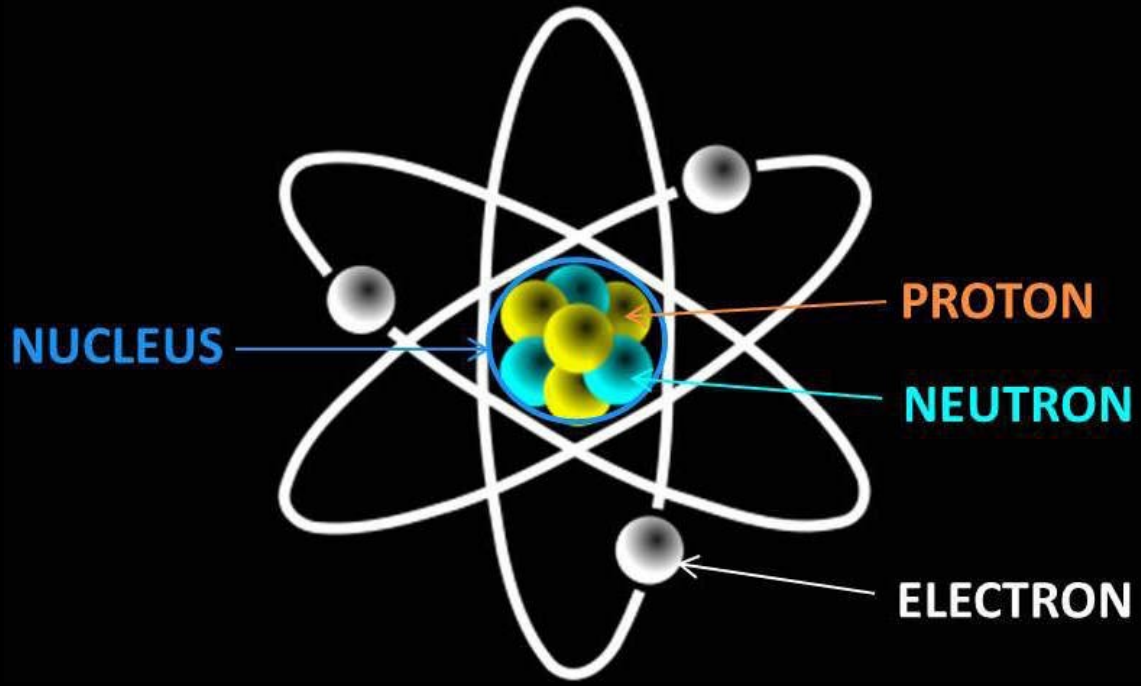
Fusion. And the last piece of the first puzzle.

Freshman seminar, INT 94TK

David Stuart, UC Santa Barbara



View of nuclear constituents in 1930's



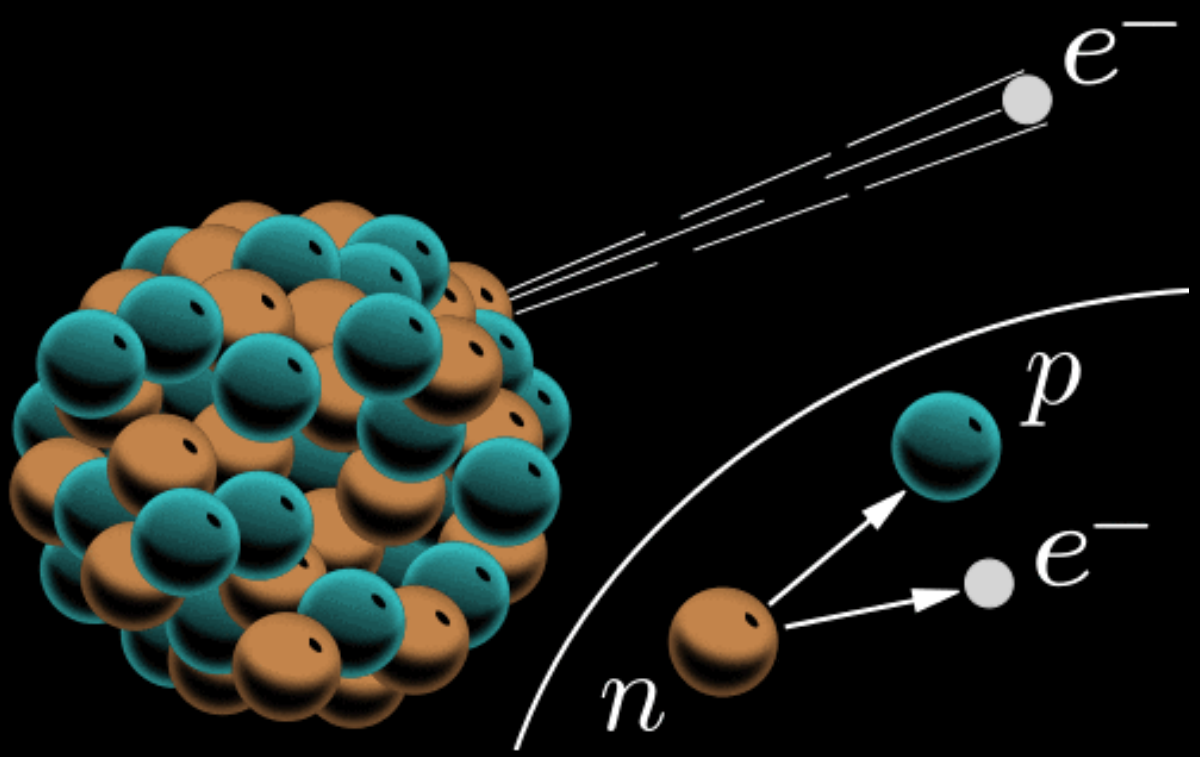
Nuclei can decay via:

α). easily absorbed
Ejected He nucleus

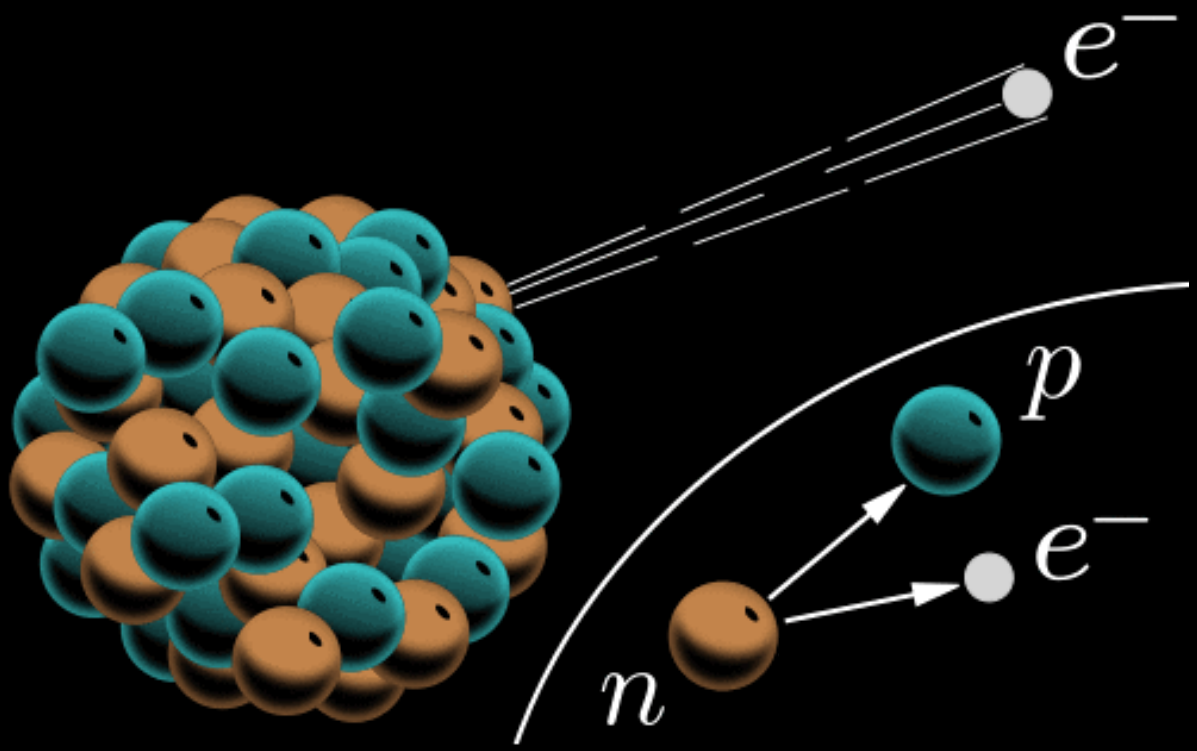
β). more penetrating
Ejected electron

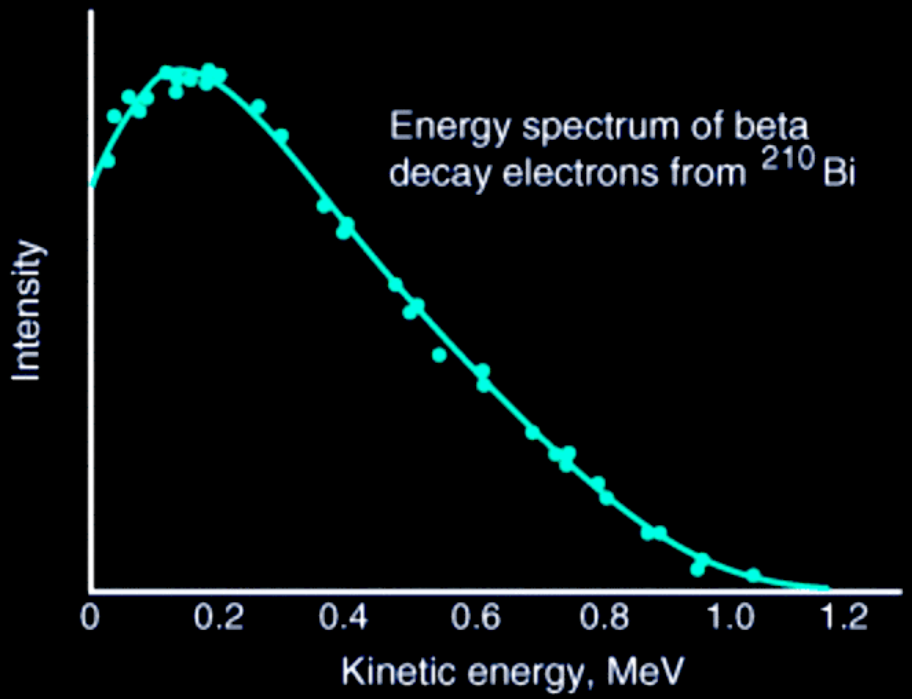
γ). very penetrating rays
De-excitation

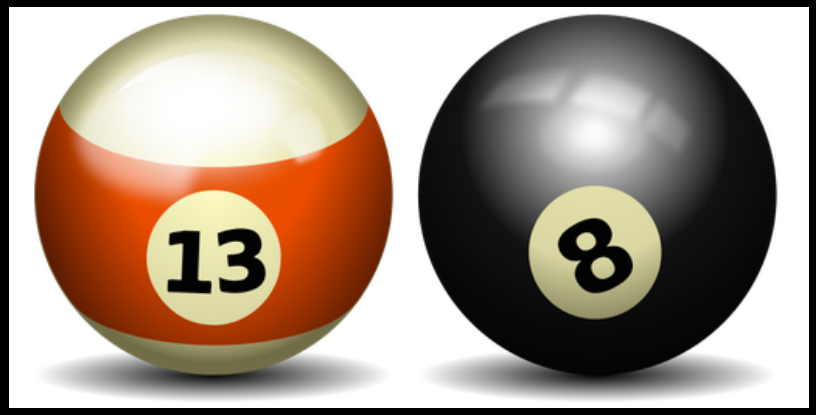
Where do the ejected electrons come from?



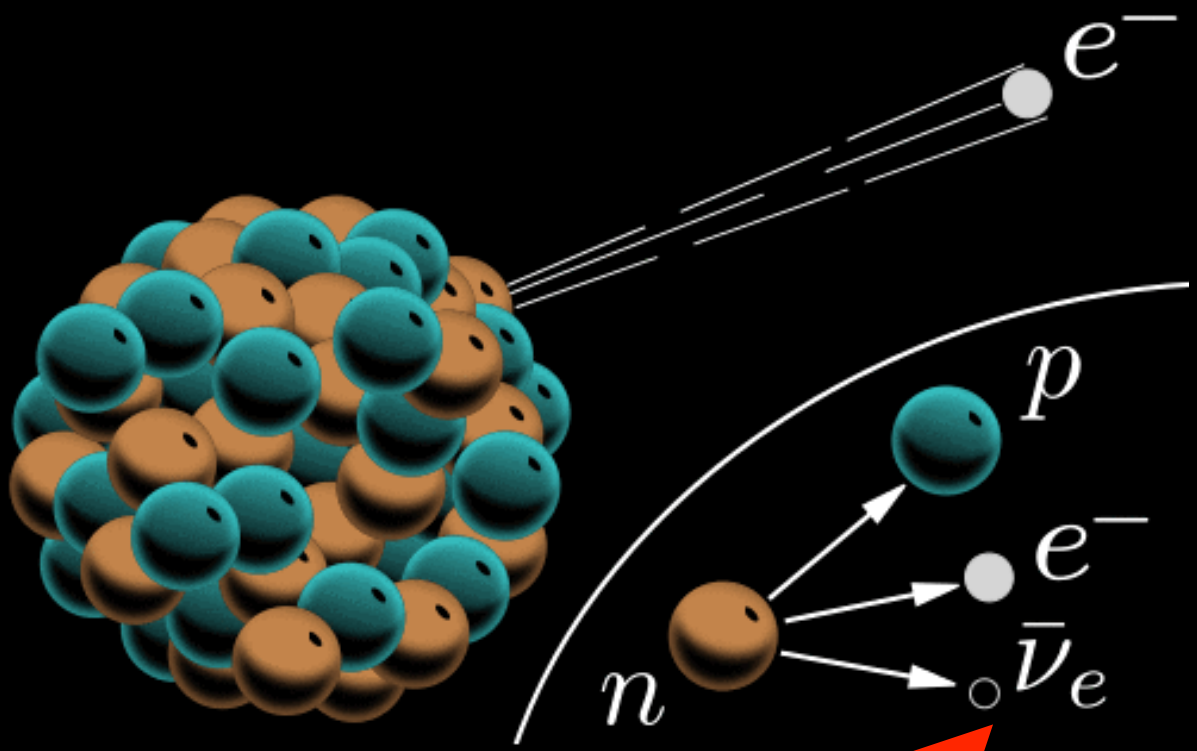
Just $n \rightarrow p^+ e^-$ violates conservation of momentum

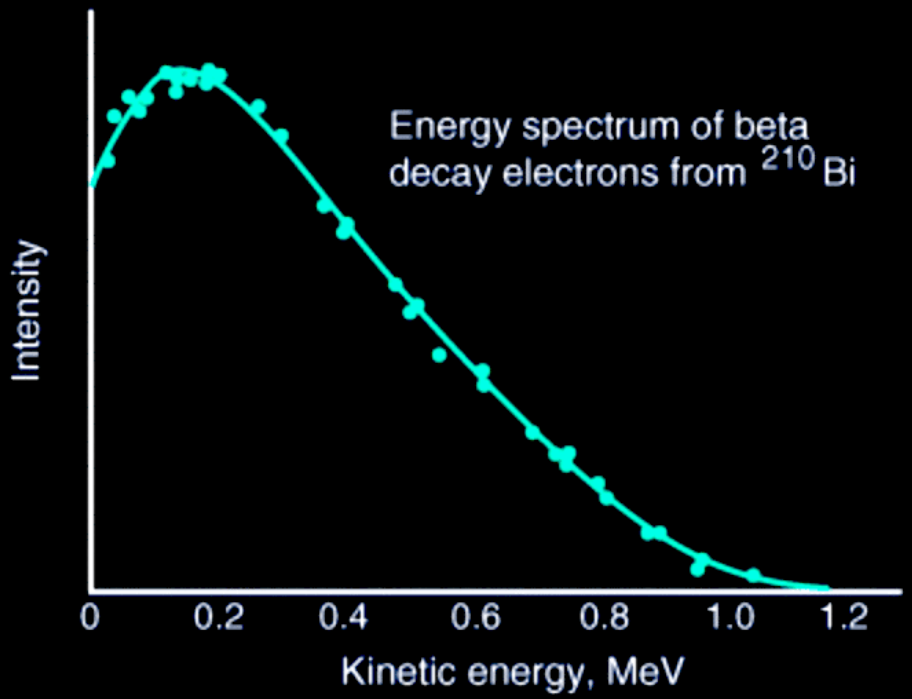


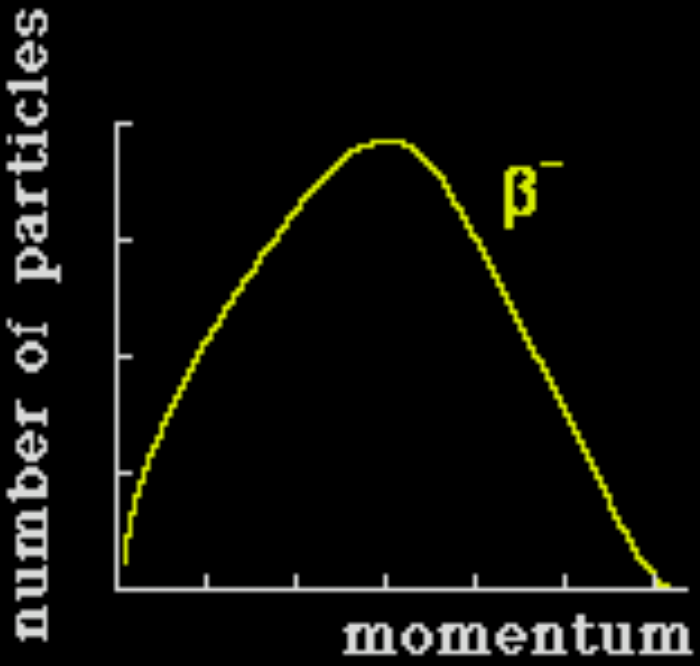




Just $n \rightarrow p^+ e^-$ violates conservation of momentum w/o a 3rd particle







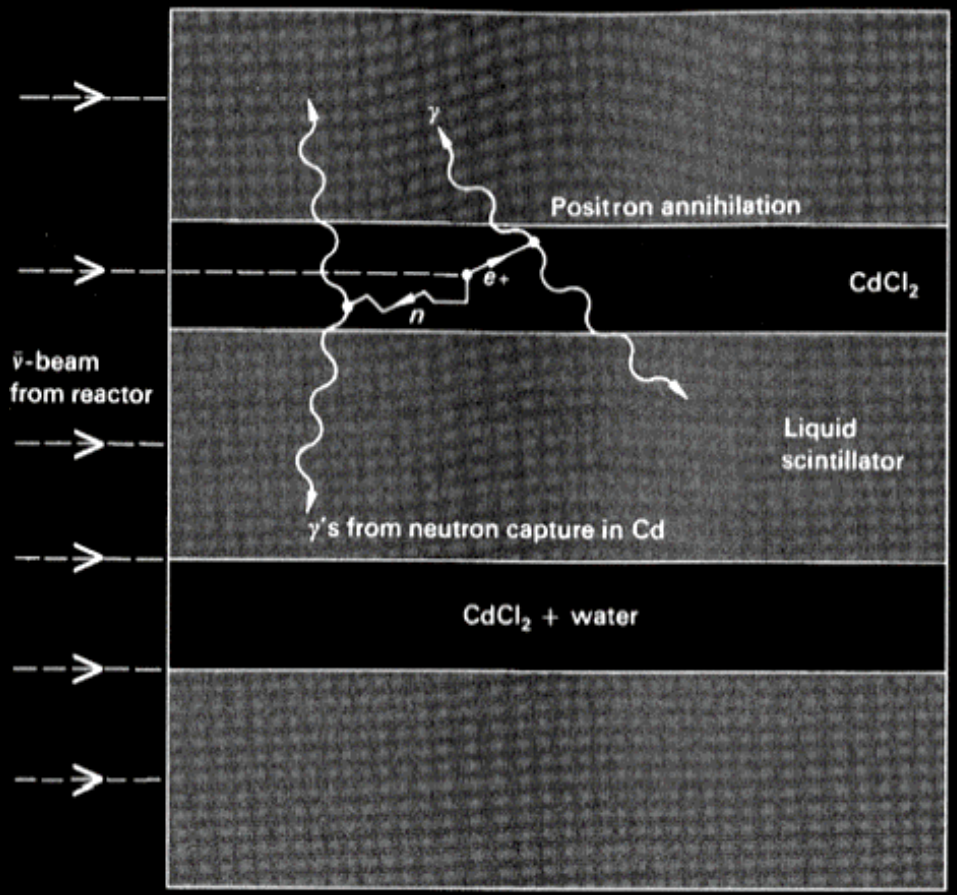
Fermi proposed a 3rd particle being produced. Neutral and apparently massless, called the neutrino.

Directly detected in 1953

Beta decay in a fission reactor corresponds to $n \rightarrow p^+ + e^- + \nu$

The process could be reversed to $\nu + p^+ \rightarrow n + e^+$
where a positron is produced by conservation of charge.

Cowan and Reines set up a detector near a fission reactor to look for neutrons and positrons being produced.



Detect the reaction products as:
e^+ rapidly annihilates and produces two gamma rays.

n slowed by water moderator captured by Cd and causes a fission producing many gamma rays. Takes a few μs.

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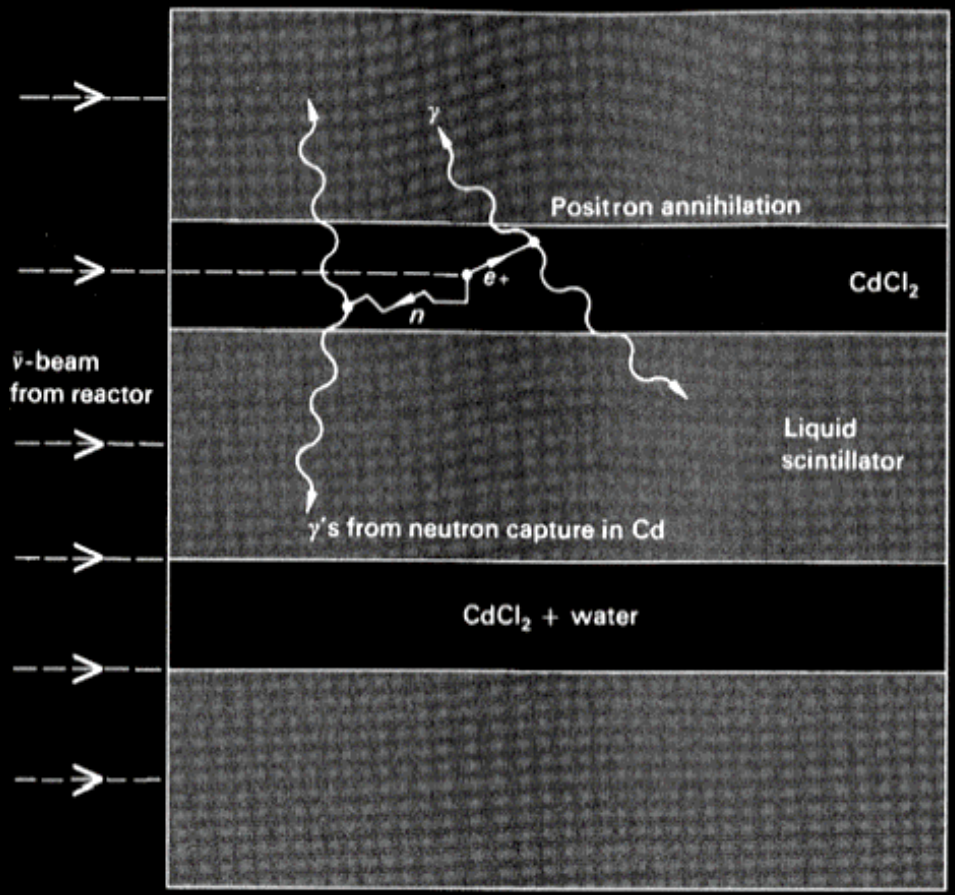

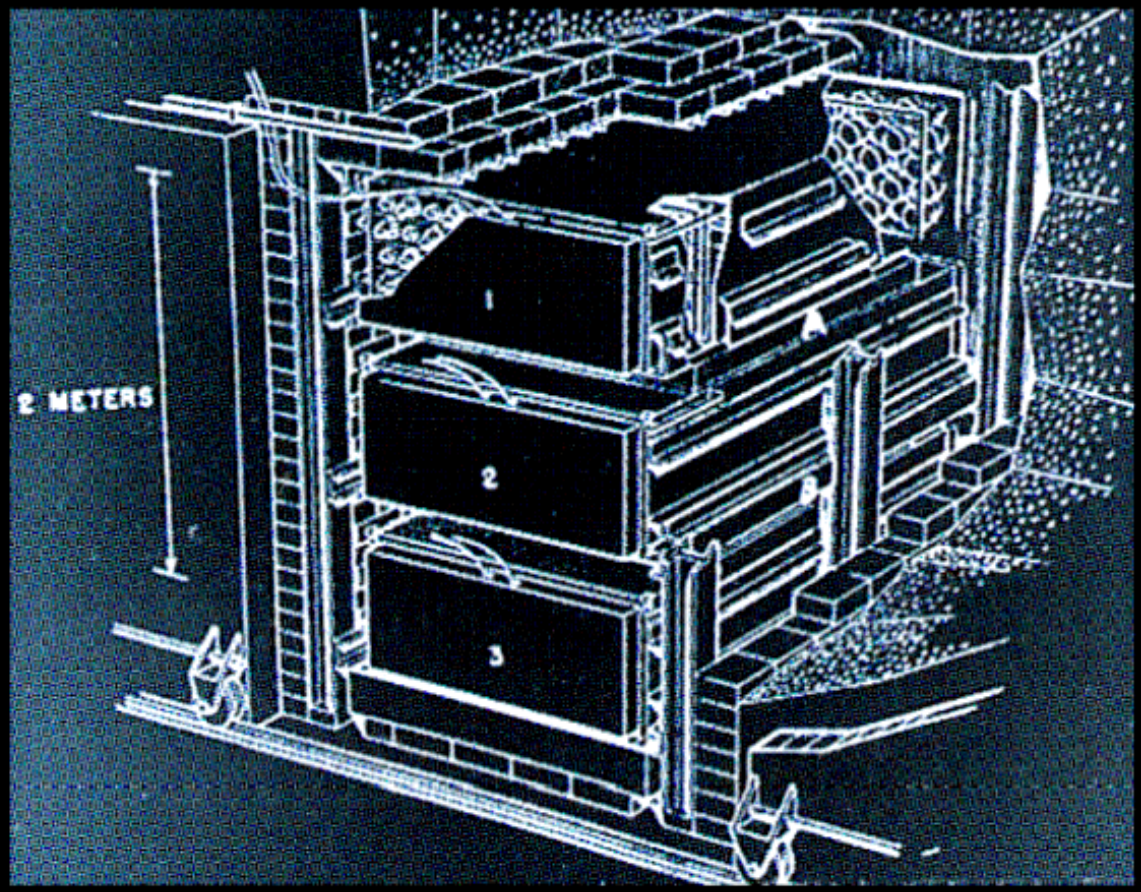

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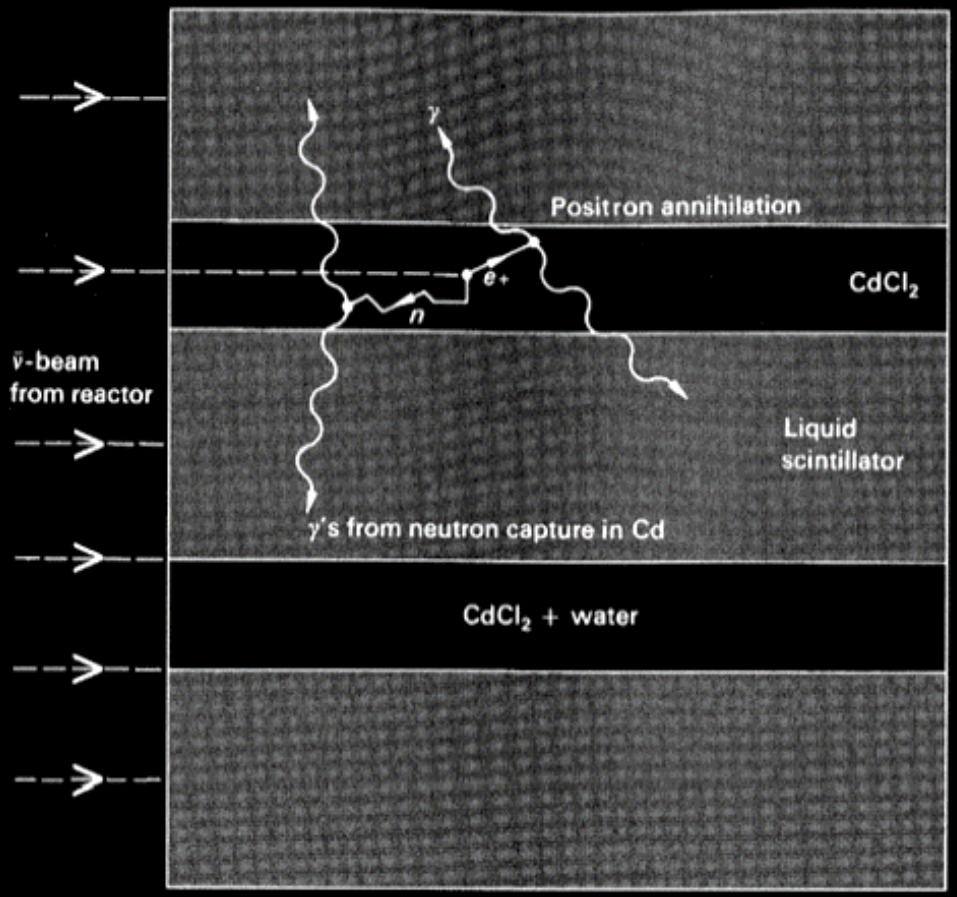

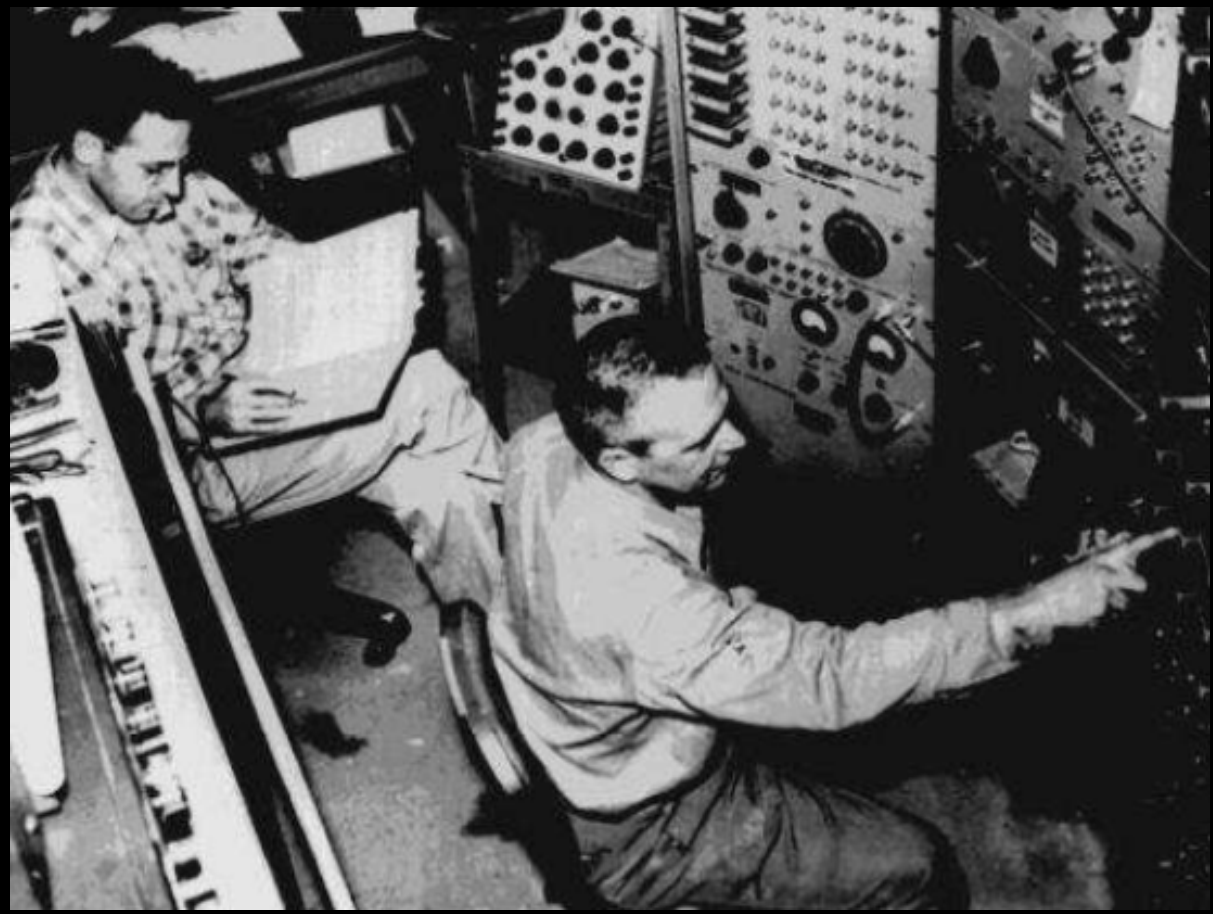

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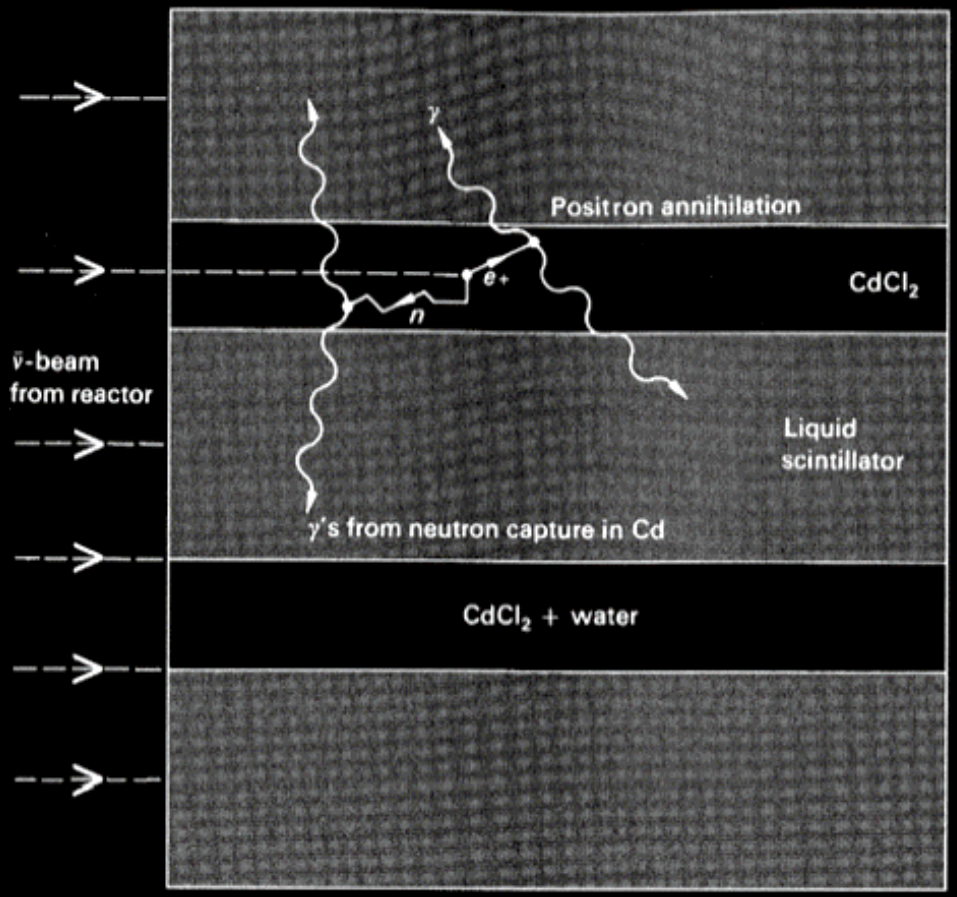
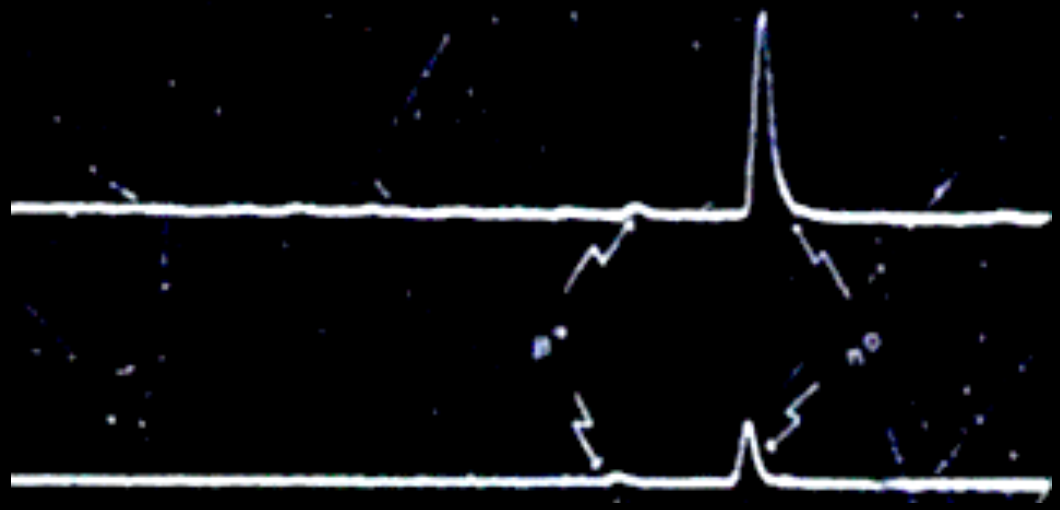
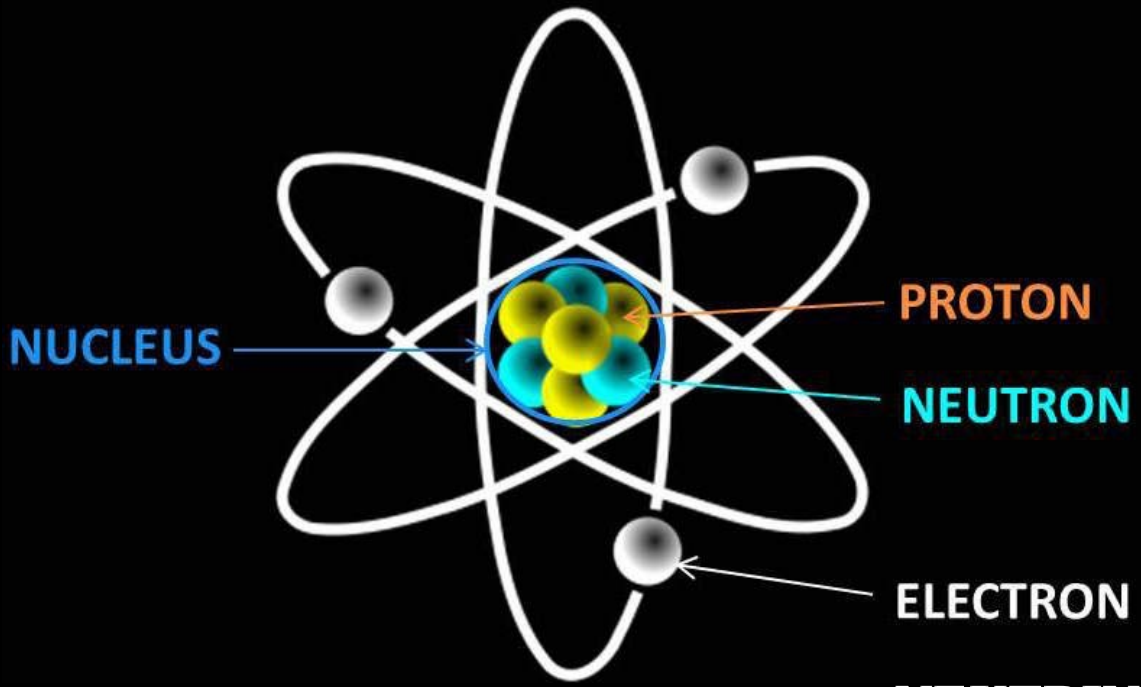




So, more modern view of constituents is:



Still much more to understand, e.g., neutrino research continues:

Large neutrino detectors near Daya Bay reactors in China

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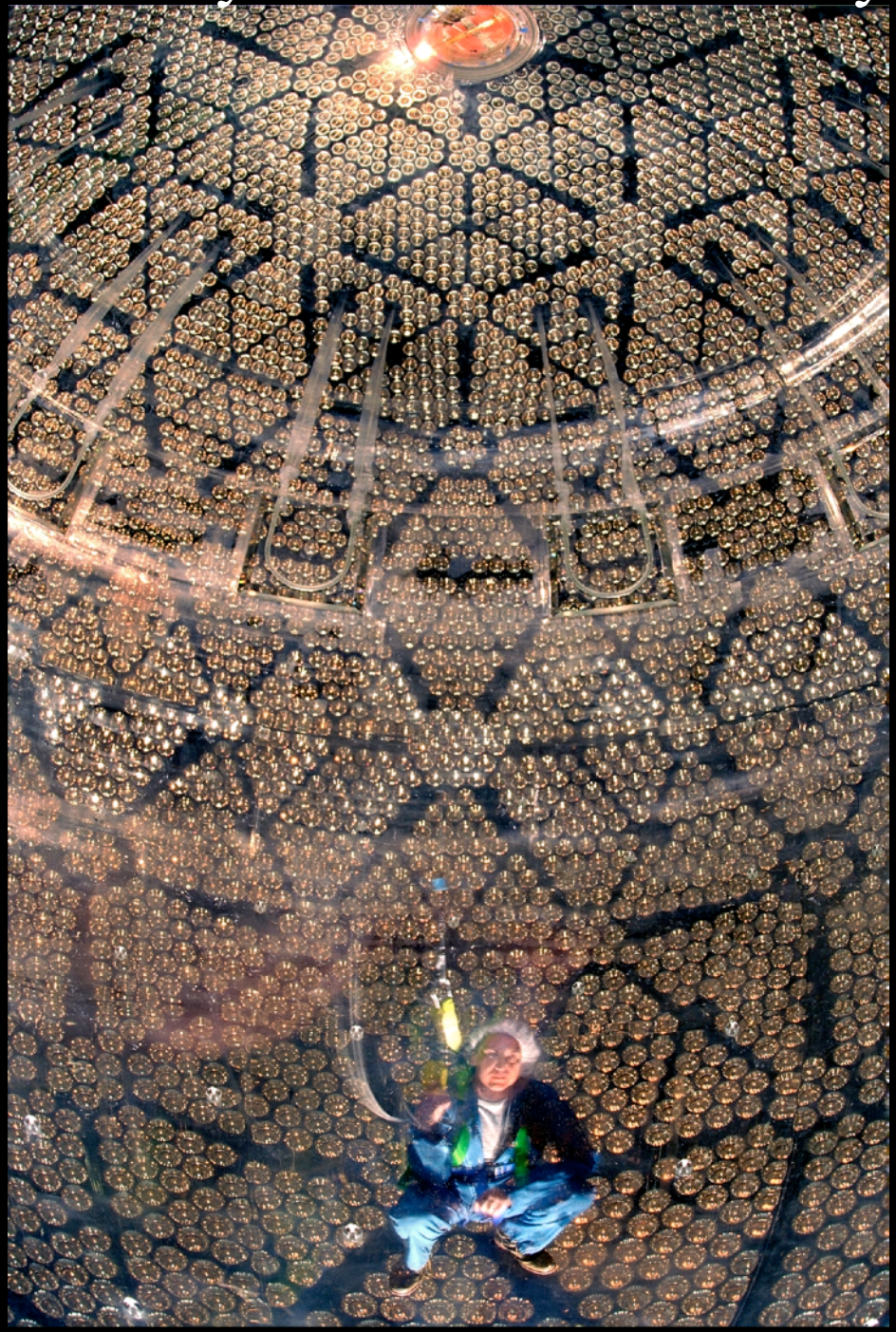
Sudbury Neutrino Observatory



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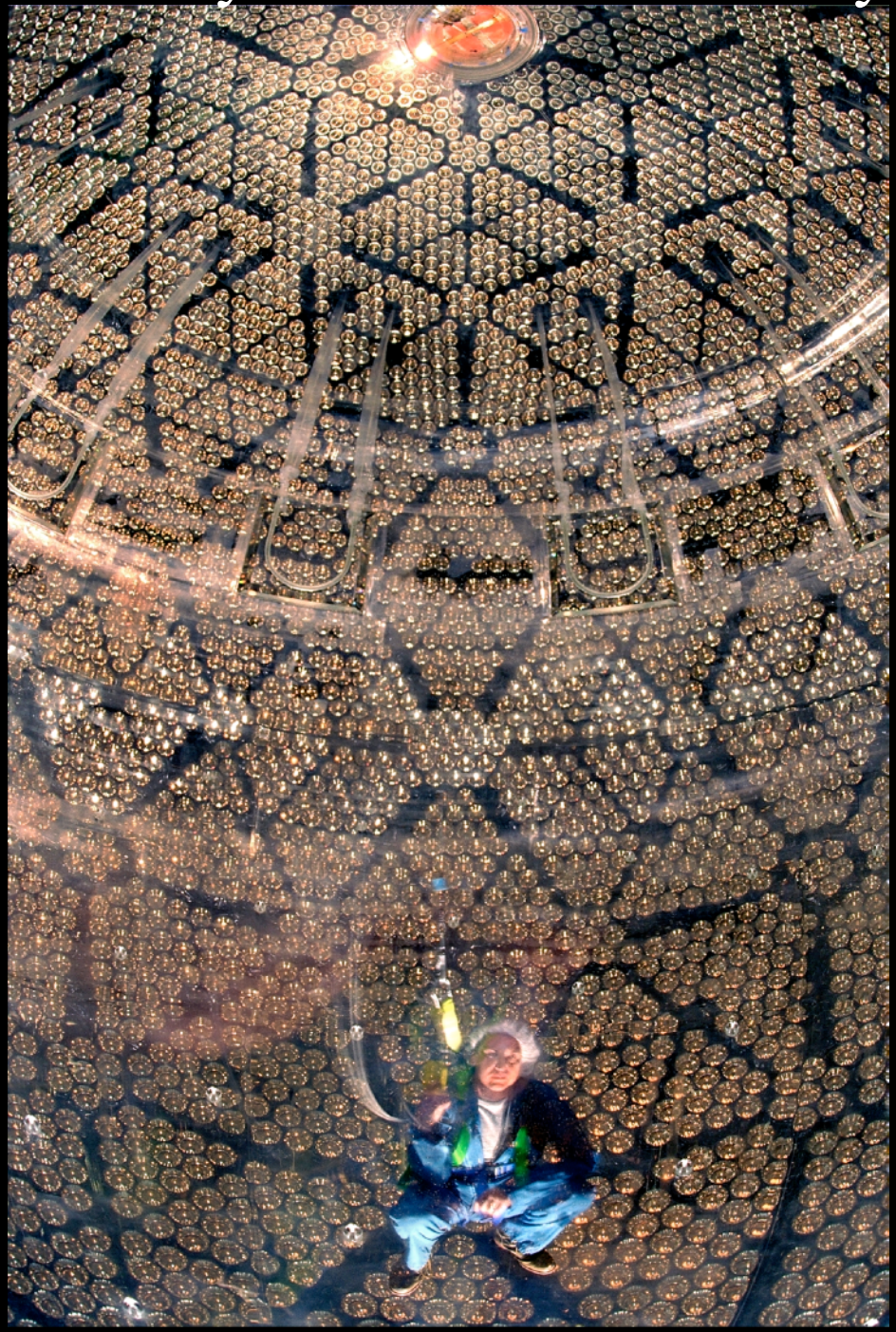
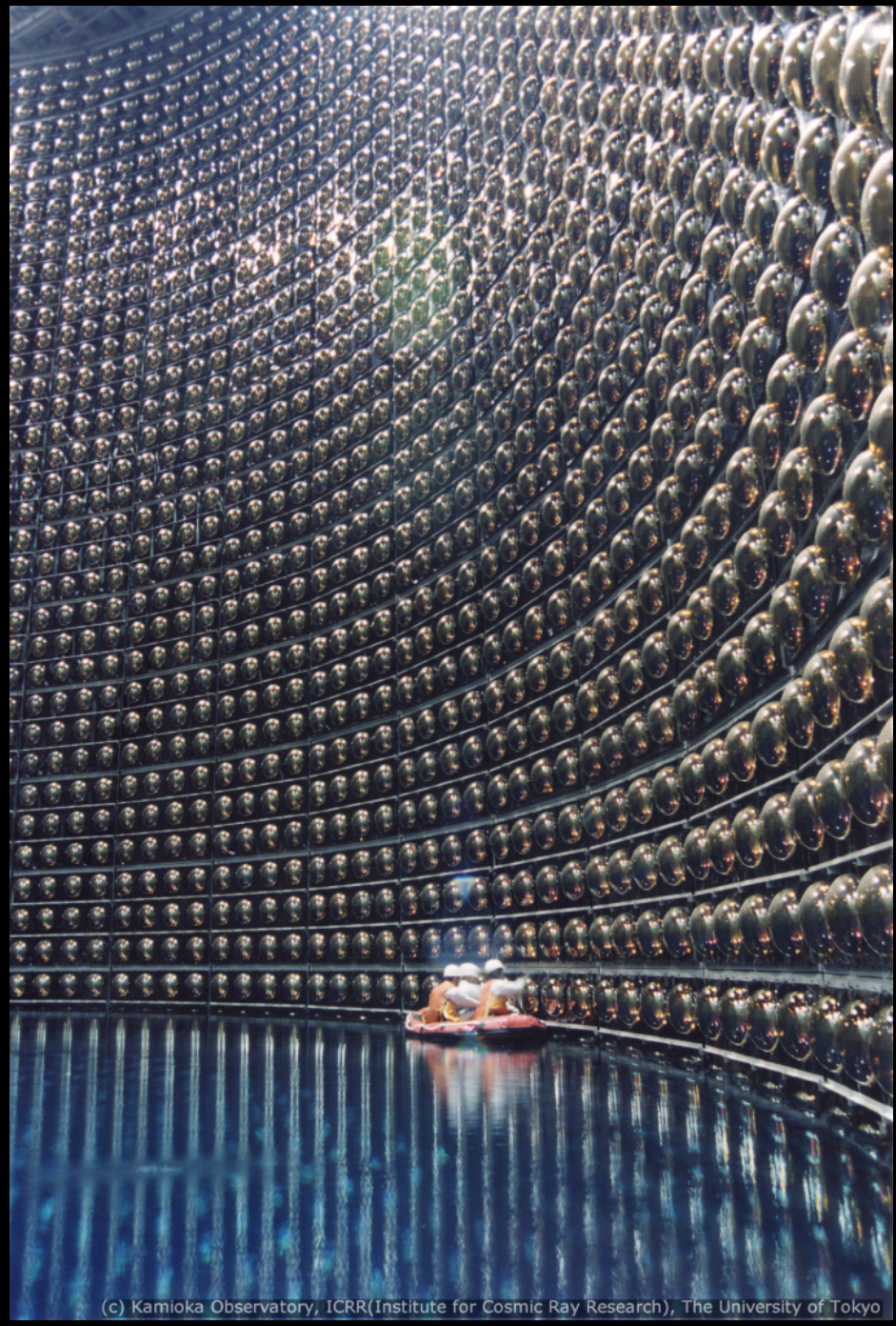


Kamiokande Neutrino Detector



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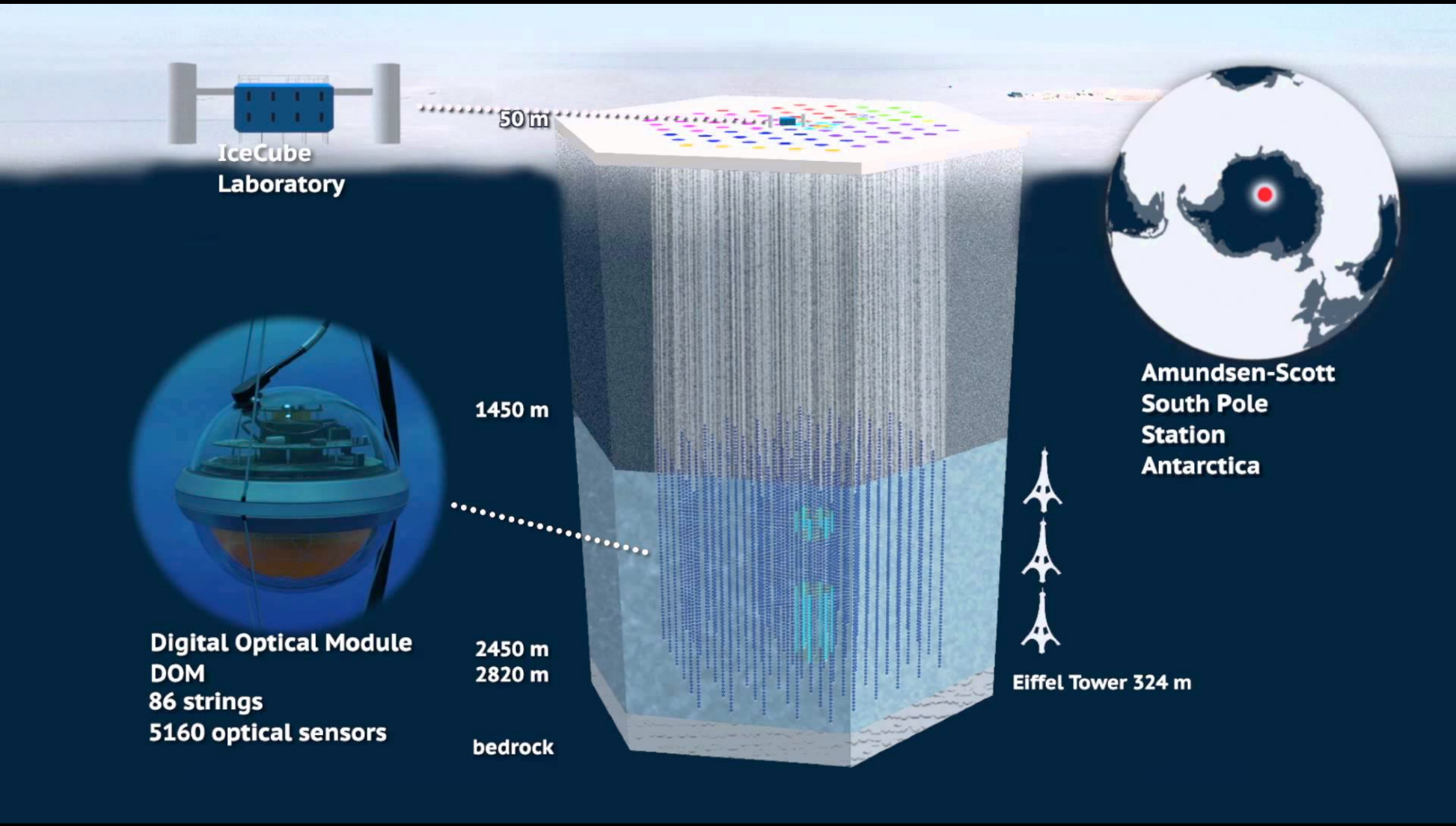
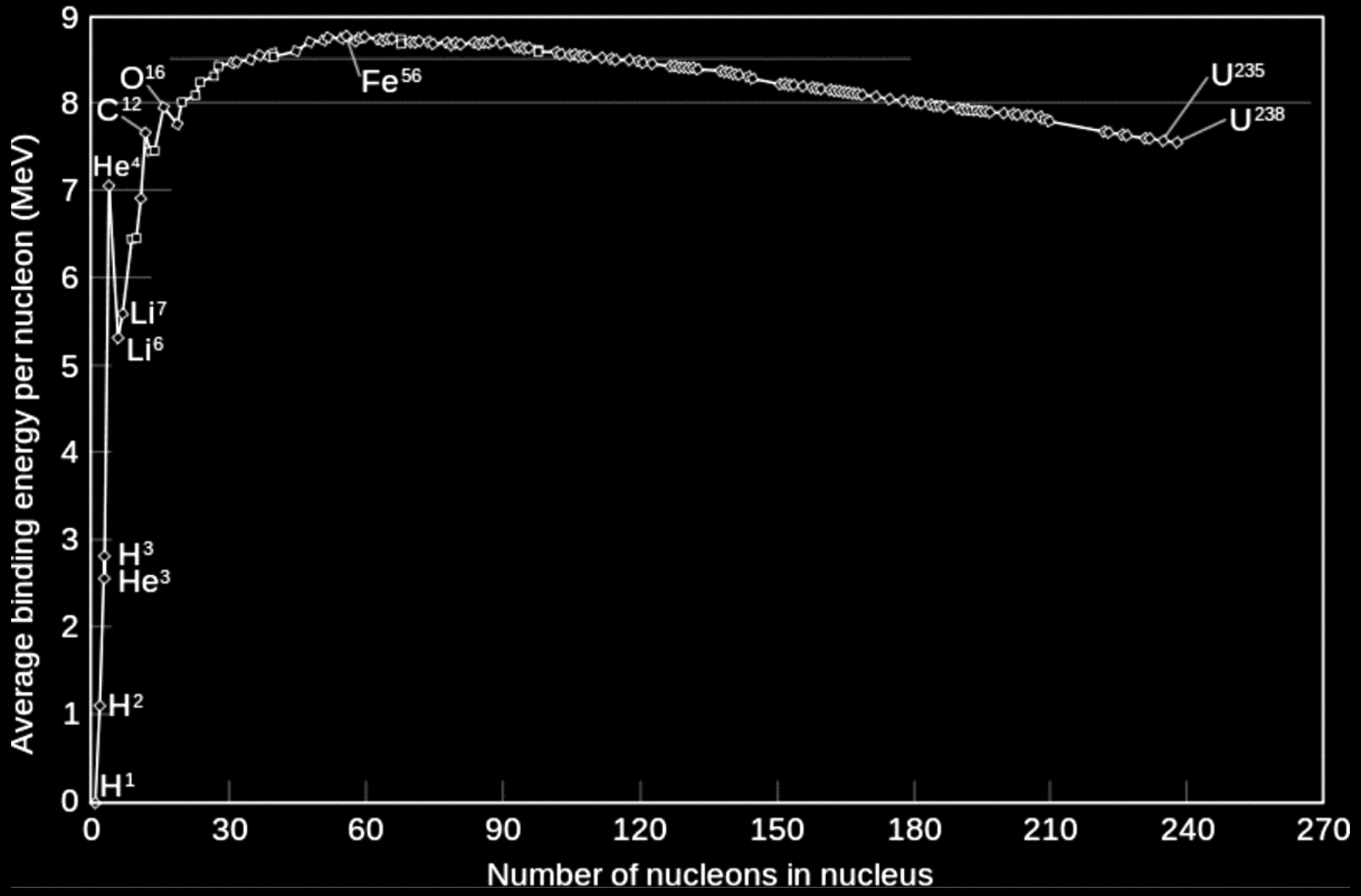
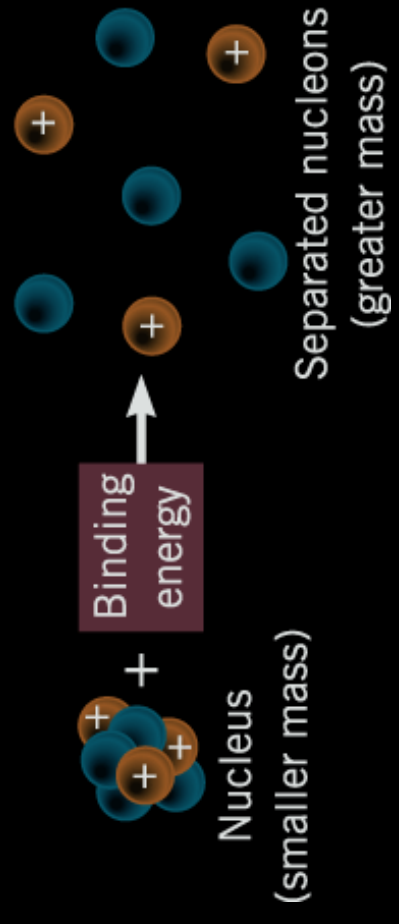
IceCube neutrino observatory



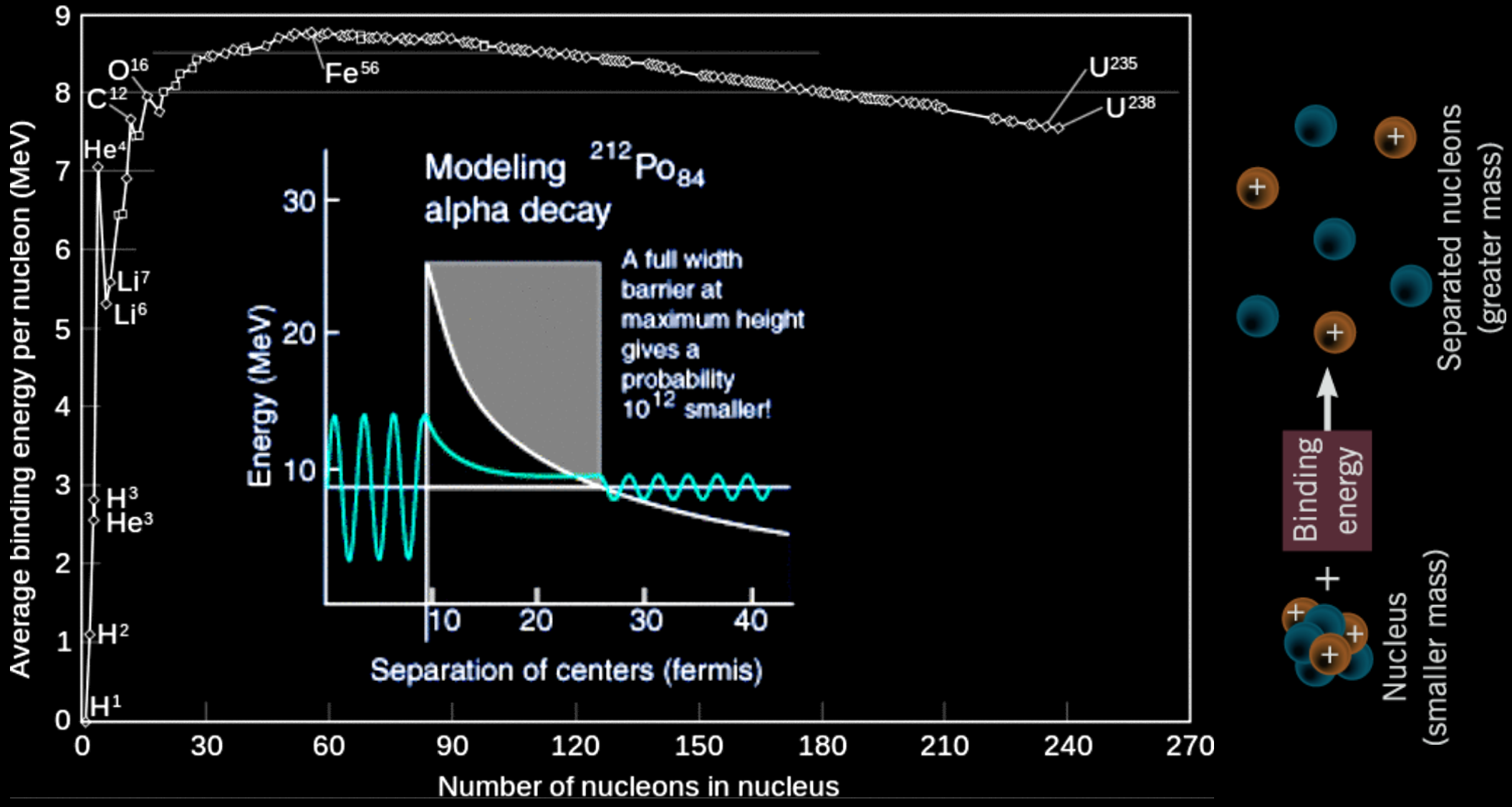
Now fusion

Fission released binding energy

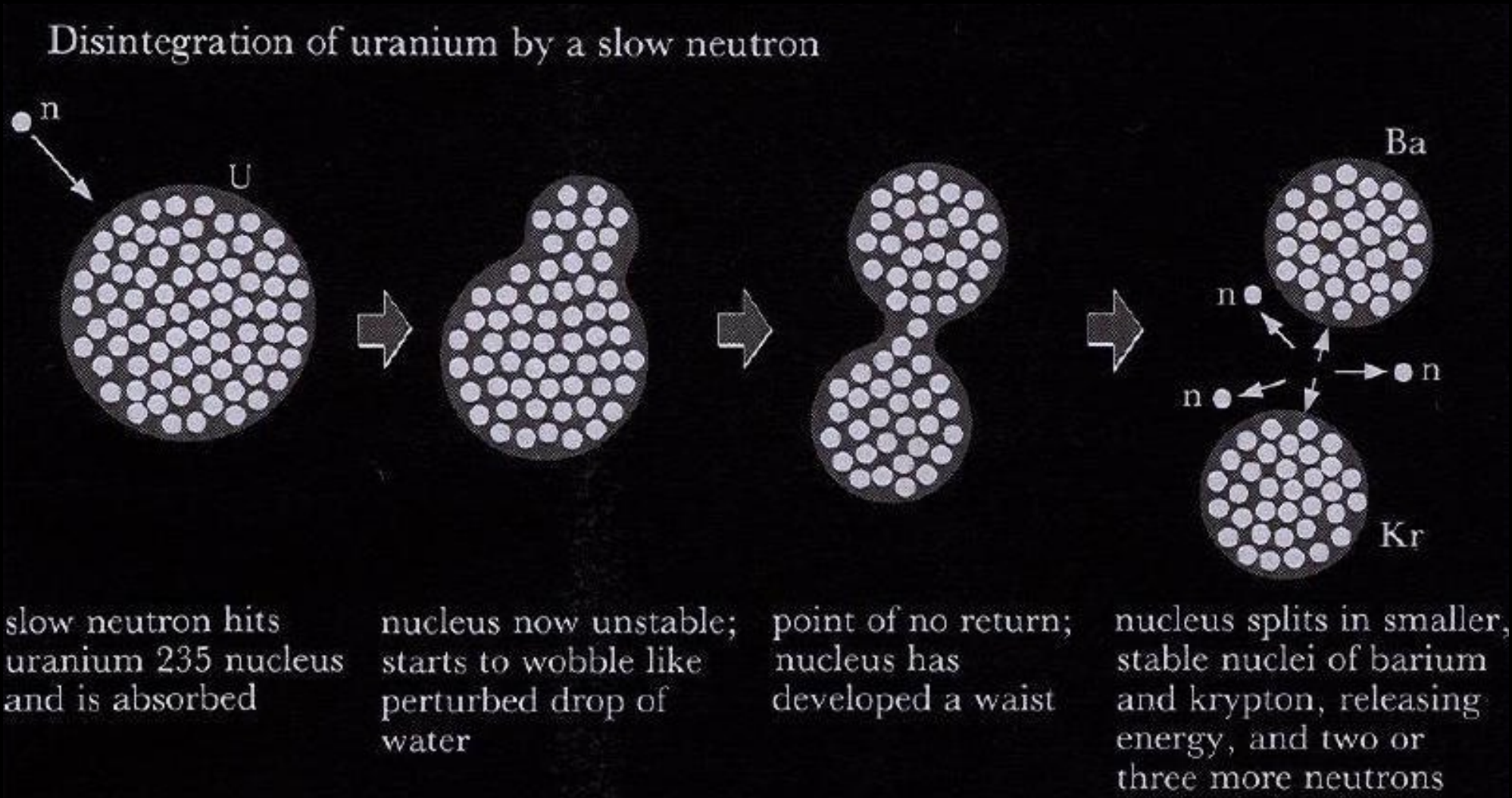




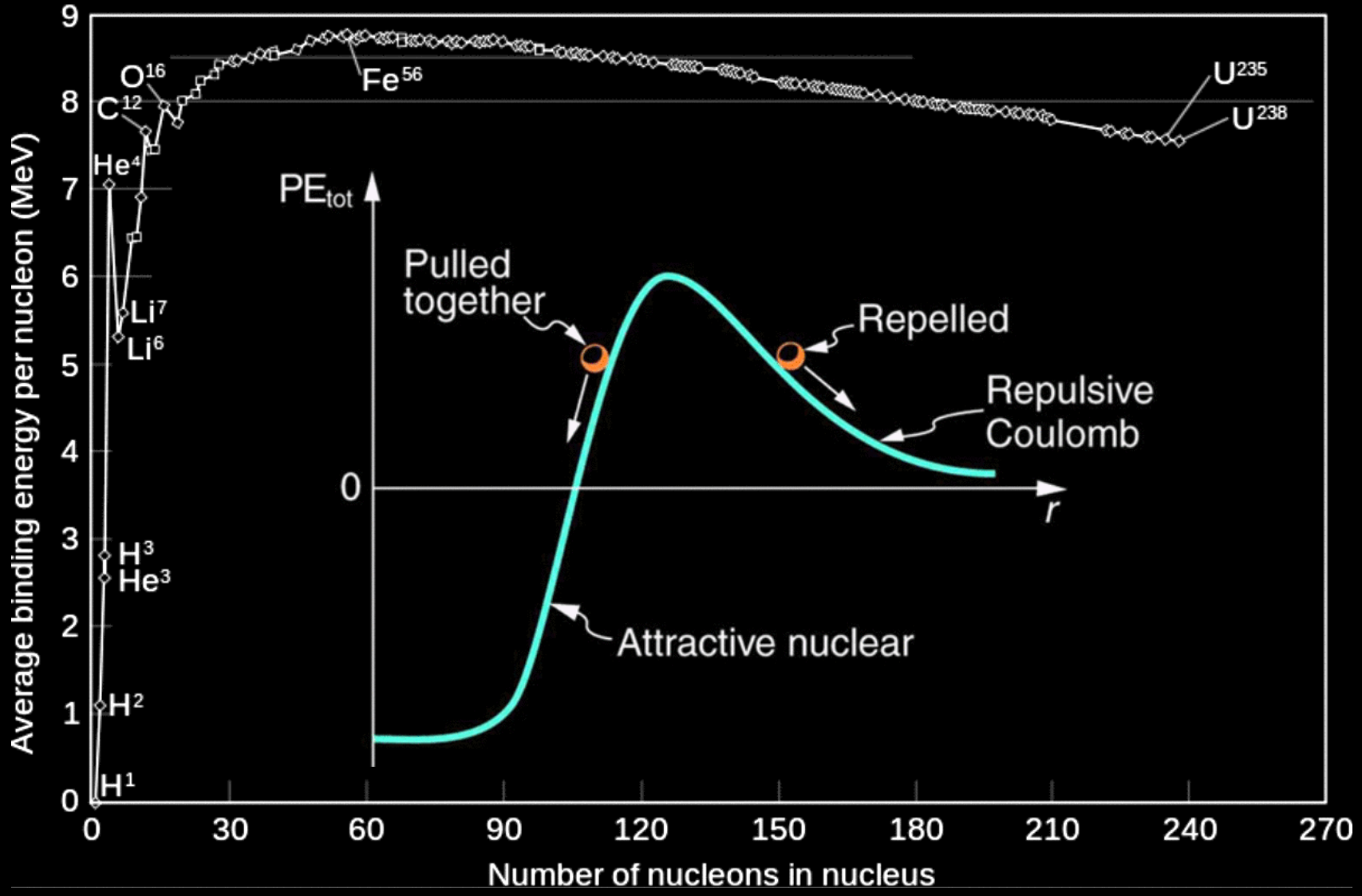
Same thing happens with alpha decay
Must overcome potential barrier, tunnel or hop.



Same thing happens with alpha decay
Must overcome potential barrier, tunnel or hop.
First splitting of atom: $p + {}^{7}Li \rightarrow \alpha + \alpha$ was a "hop"
Fission is a "hop".



To go the other way, fusing low A to higher A, also involves a potential barrier. So, shoot them together, similar to Cockroft-Walton's $p + {}^{7}Li \rightarrow \alpha + \alpha$



Mark Oliphant used the Cockroft-Walton HV approach to fire protons on targets, then deuterons (pn) from heavy water.

Just like CW, used ZincSulfide screens to detect particles.
Used a spectrometer to measure mass and energy of products.

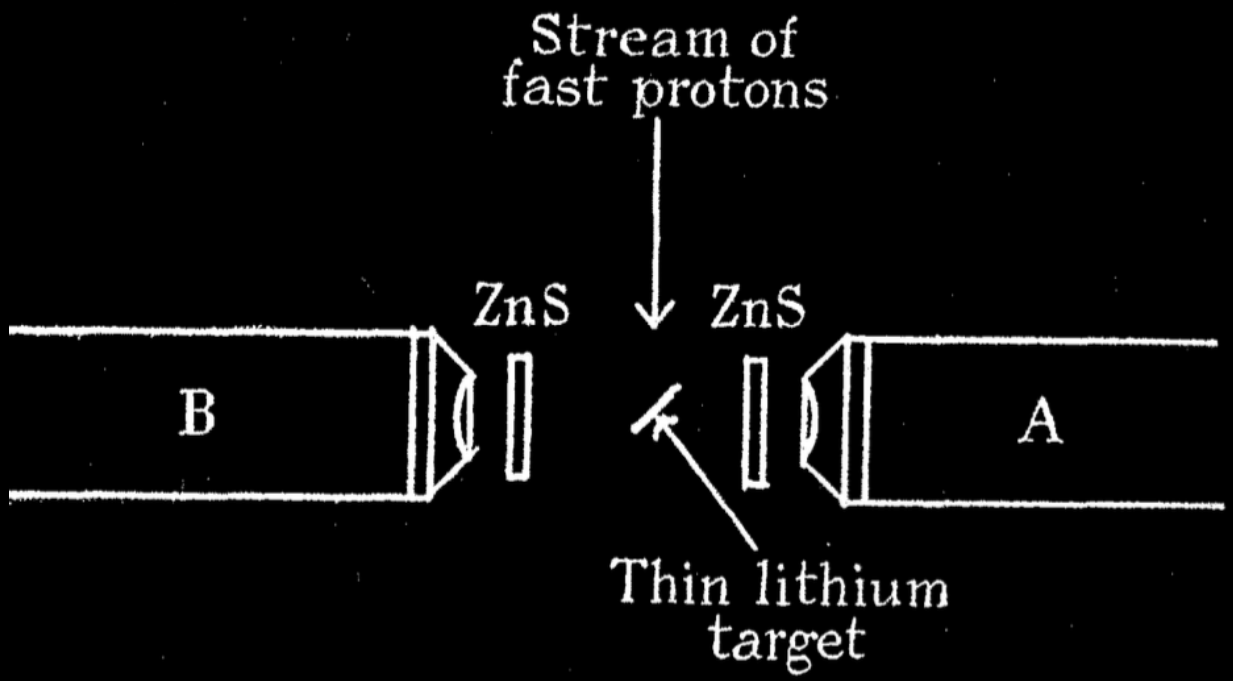
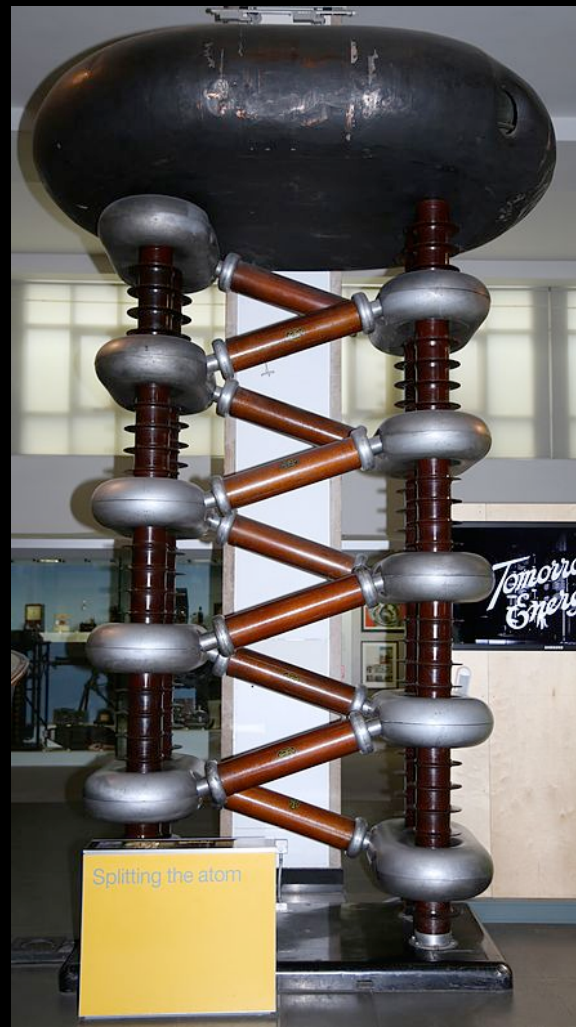


Fig. 5.



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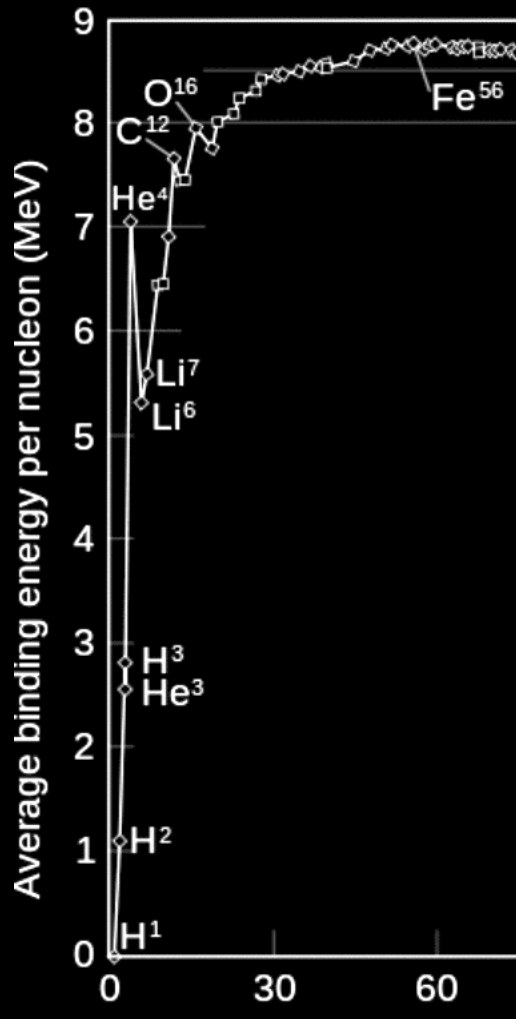
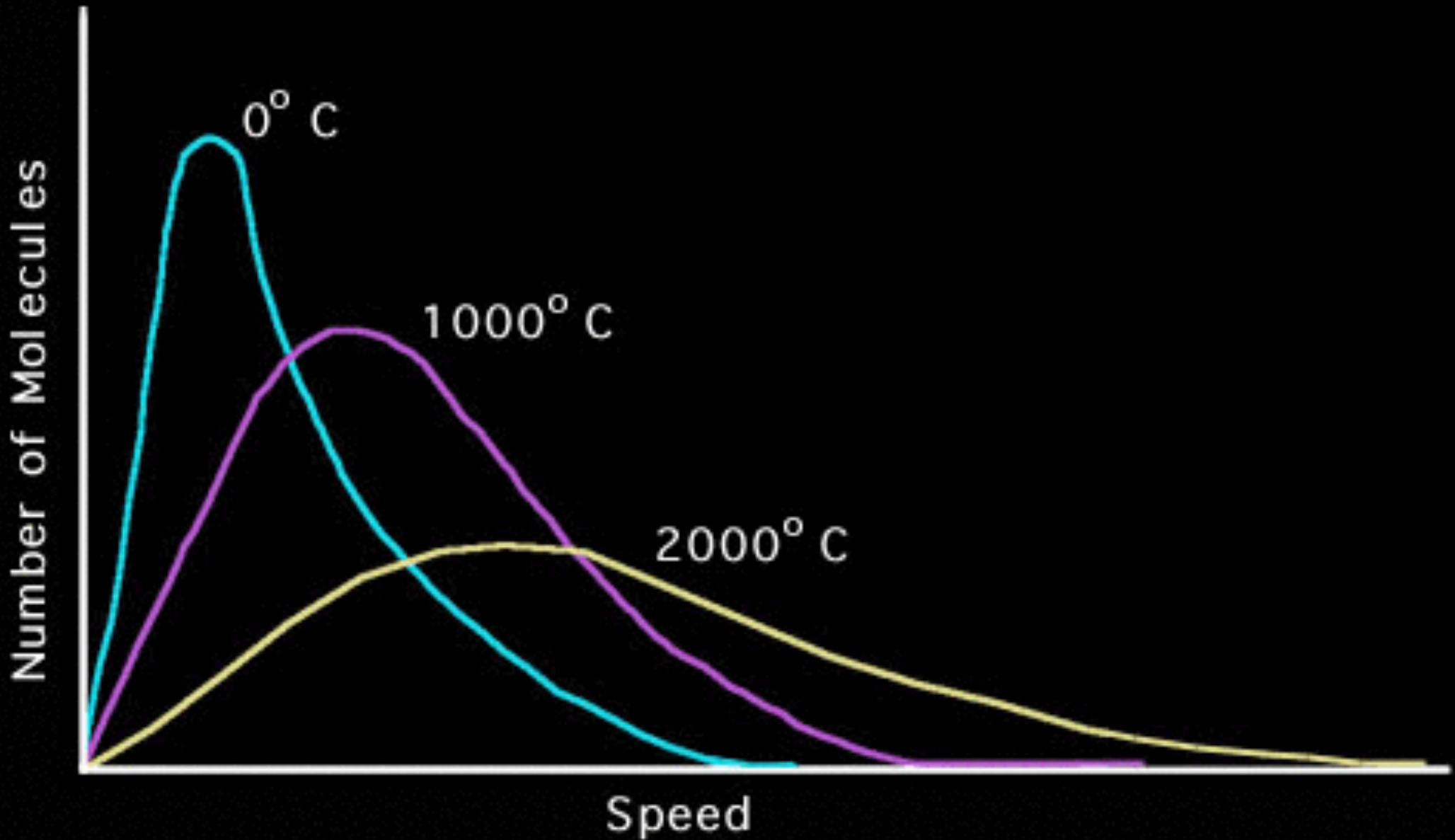
Discovered H-3 (tritons = pnn) and He-3 (ppn) in 1934.

Found that these products had more energy than was input to the process.
→Binding energy released from fusing nuclei.



Stars do this using high temperature to get high energy



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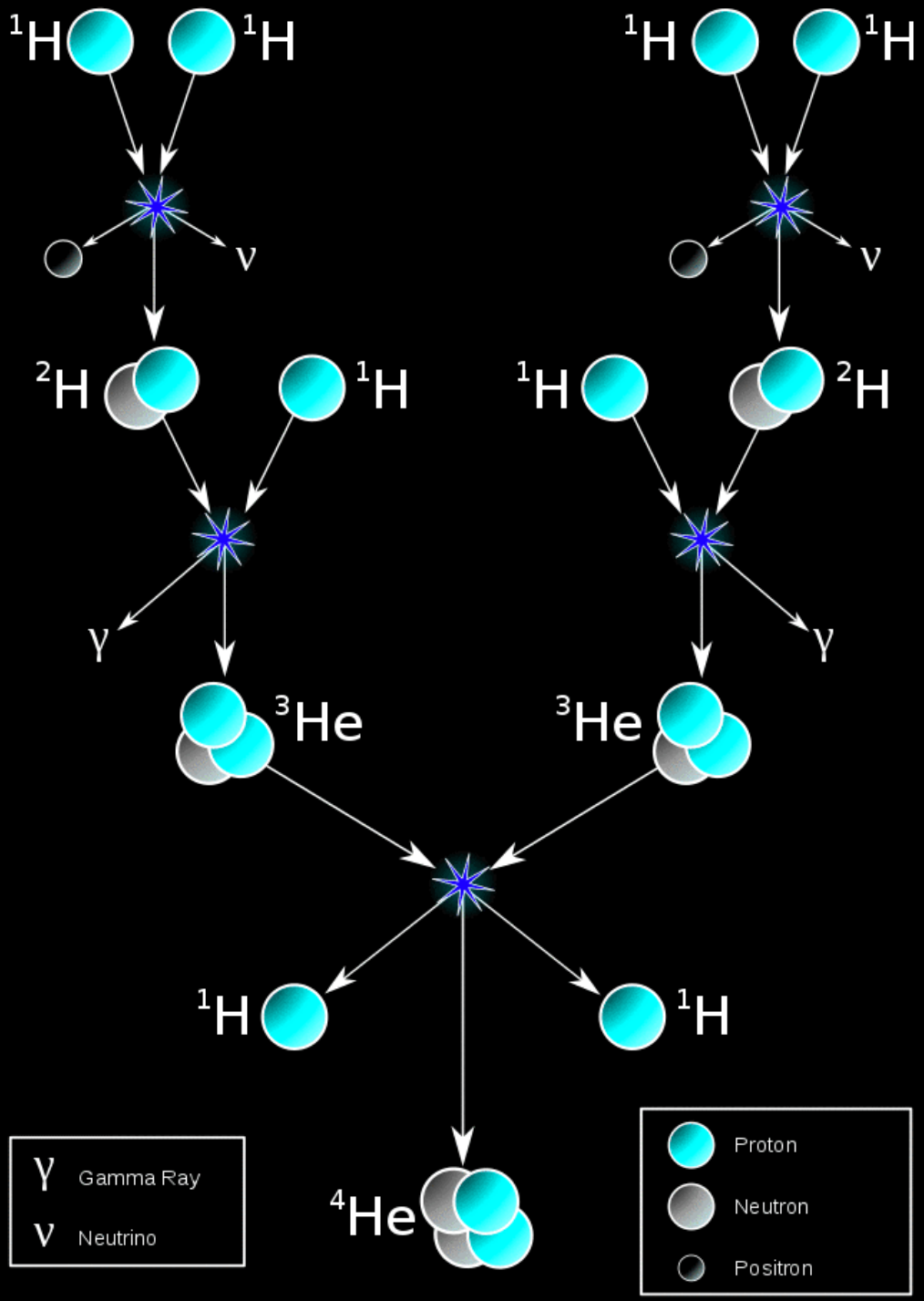

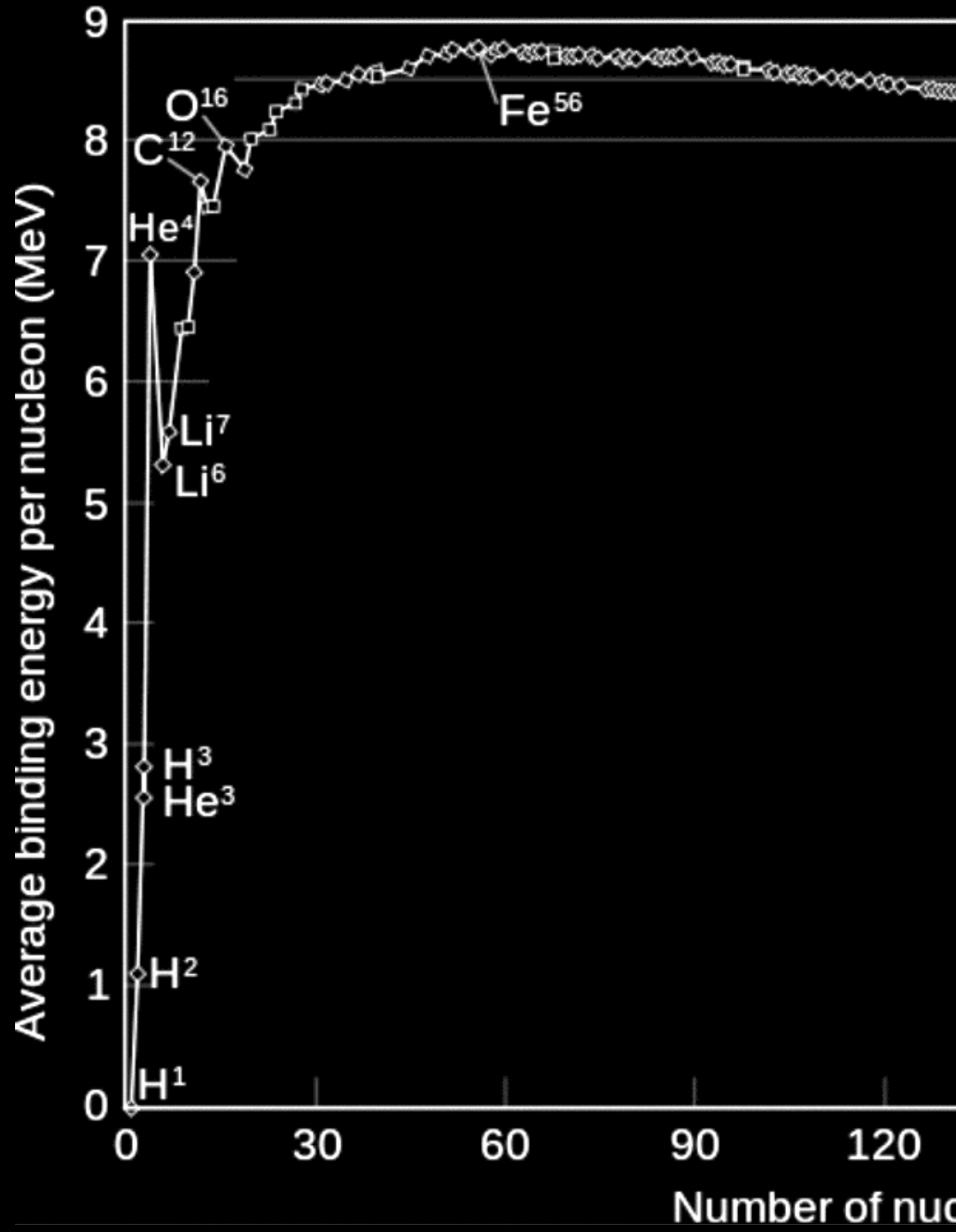

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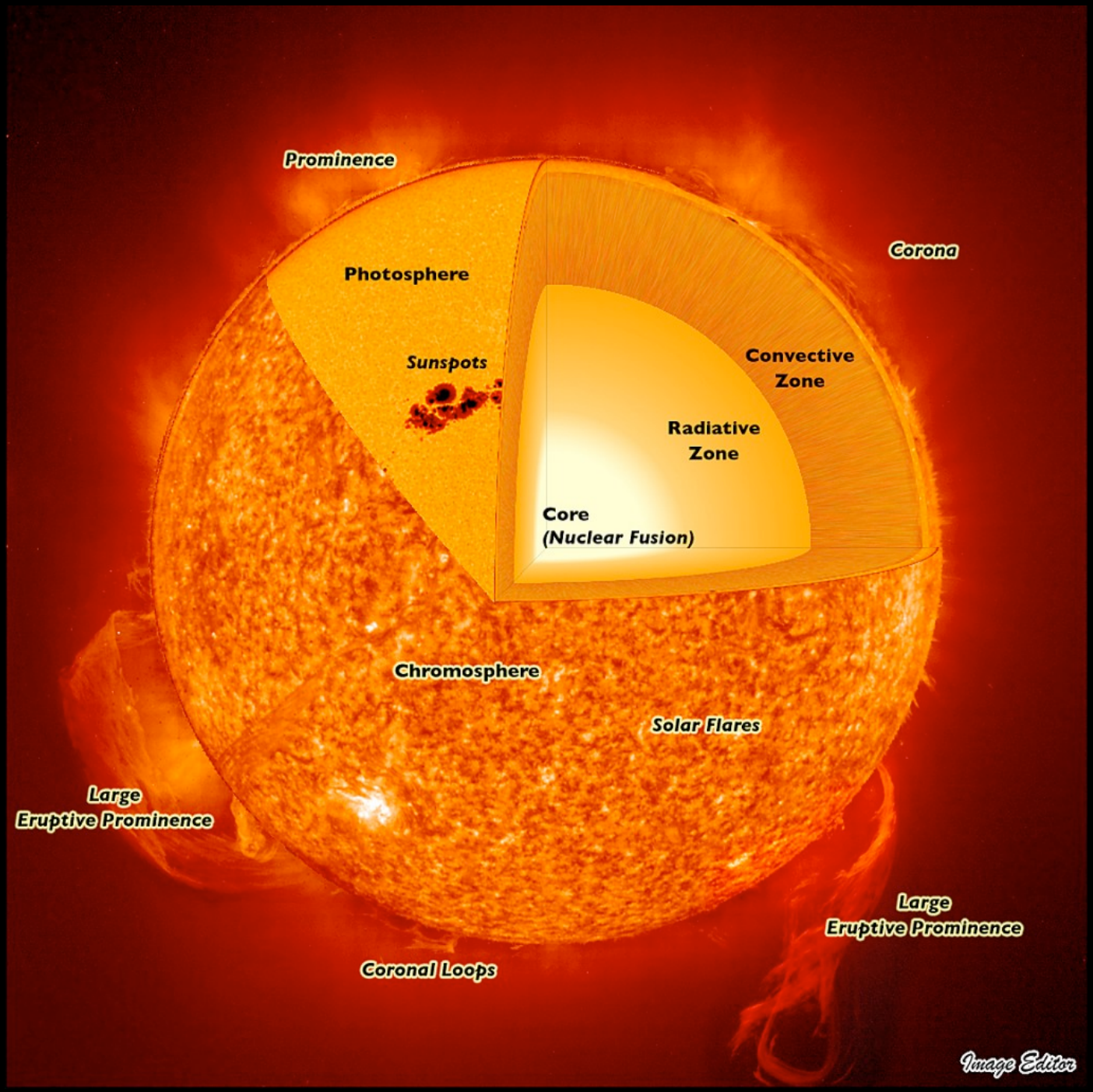
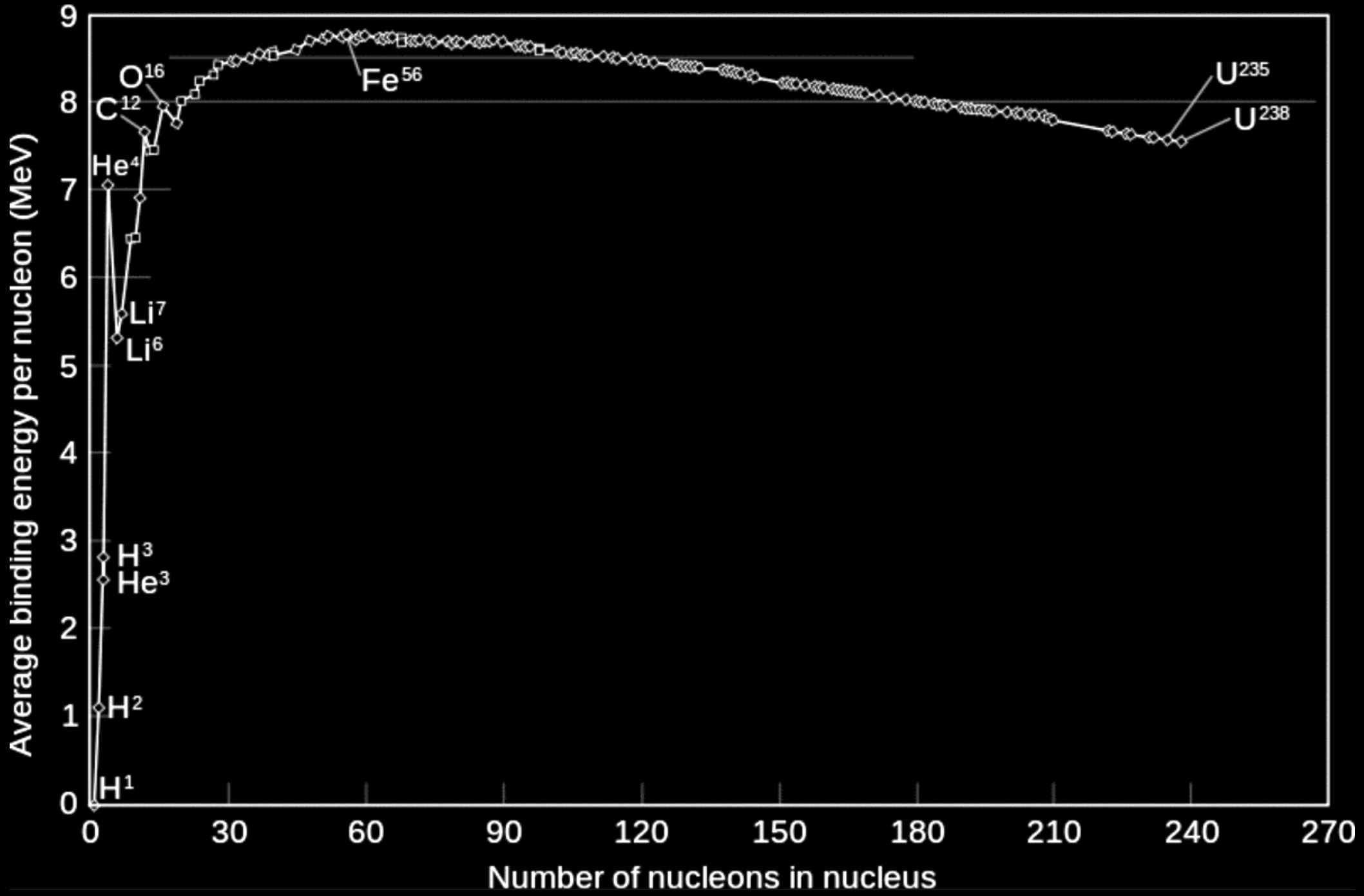


Pop quiz: If fusion is only exothermic up to iron, whence U?



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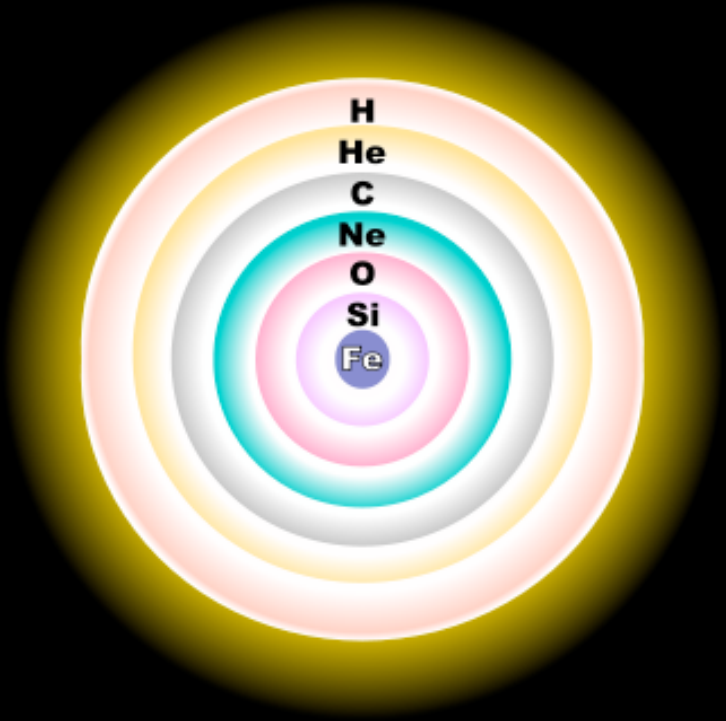

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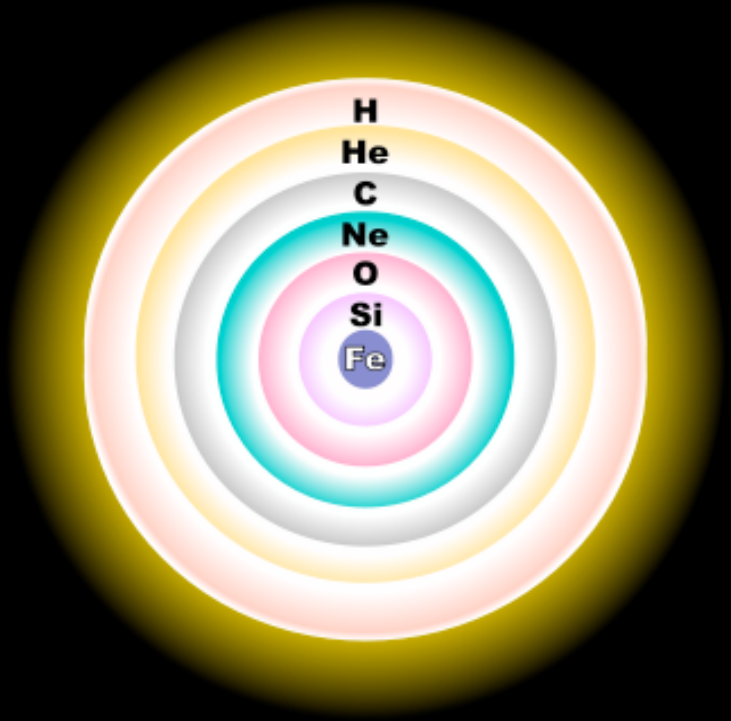

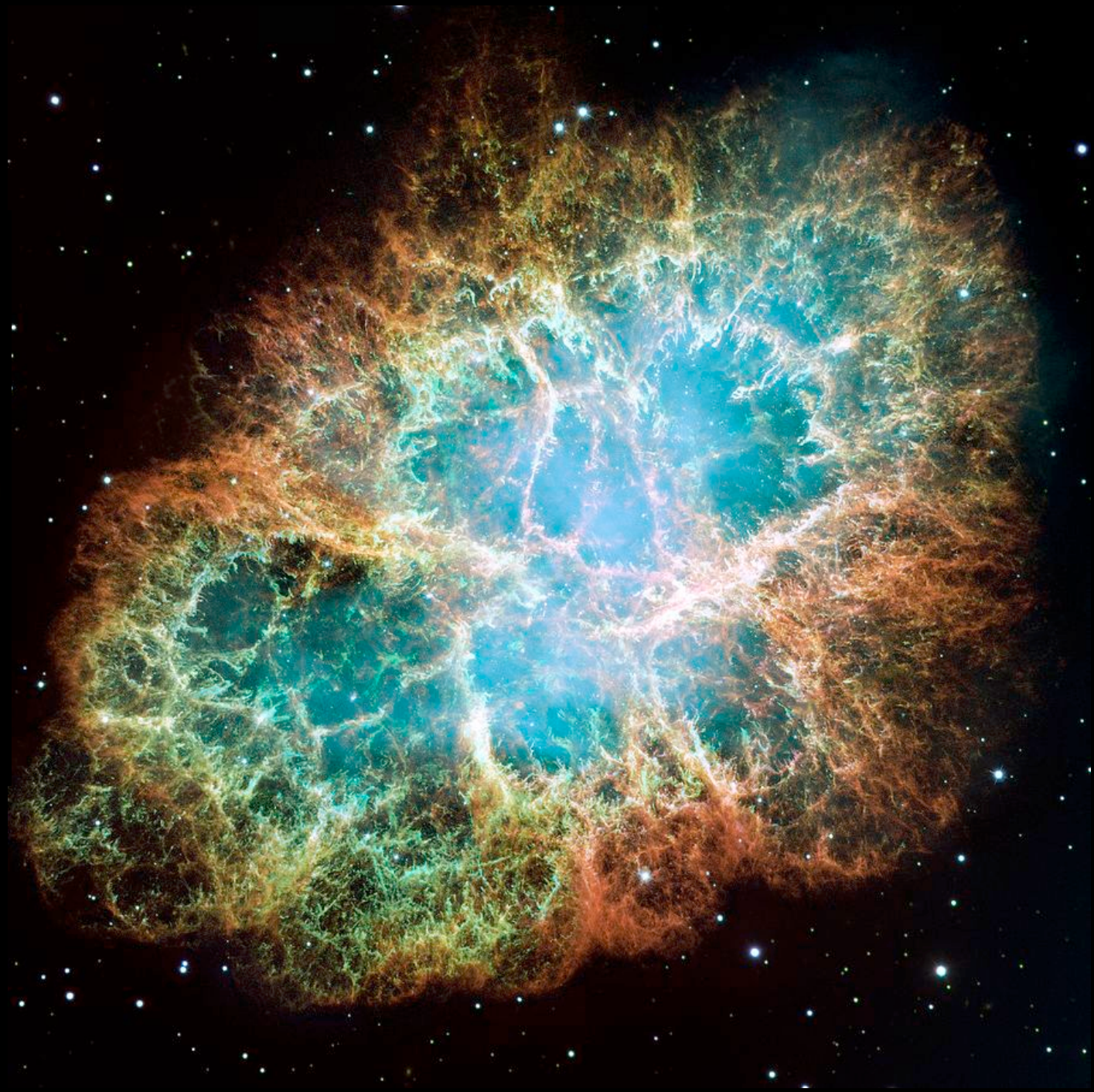

Can we use fusion for electricity production?
Three challenges: attain high input energy density, safely confine the fuel, safely convert power output to electricity.

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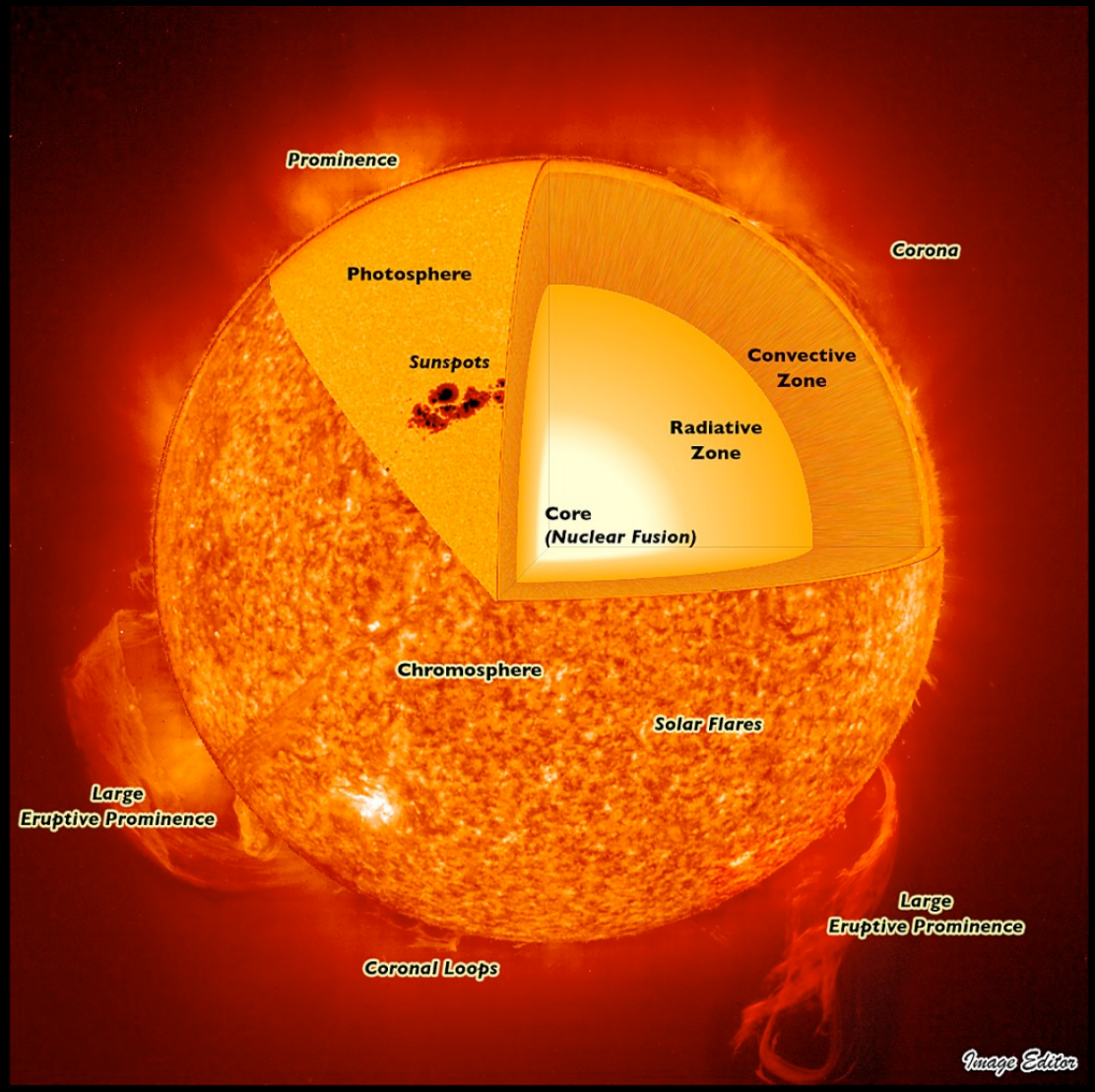
Stars use gravitational confinement



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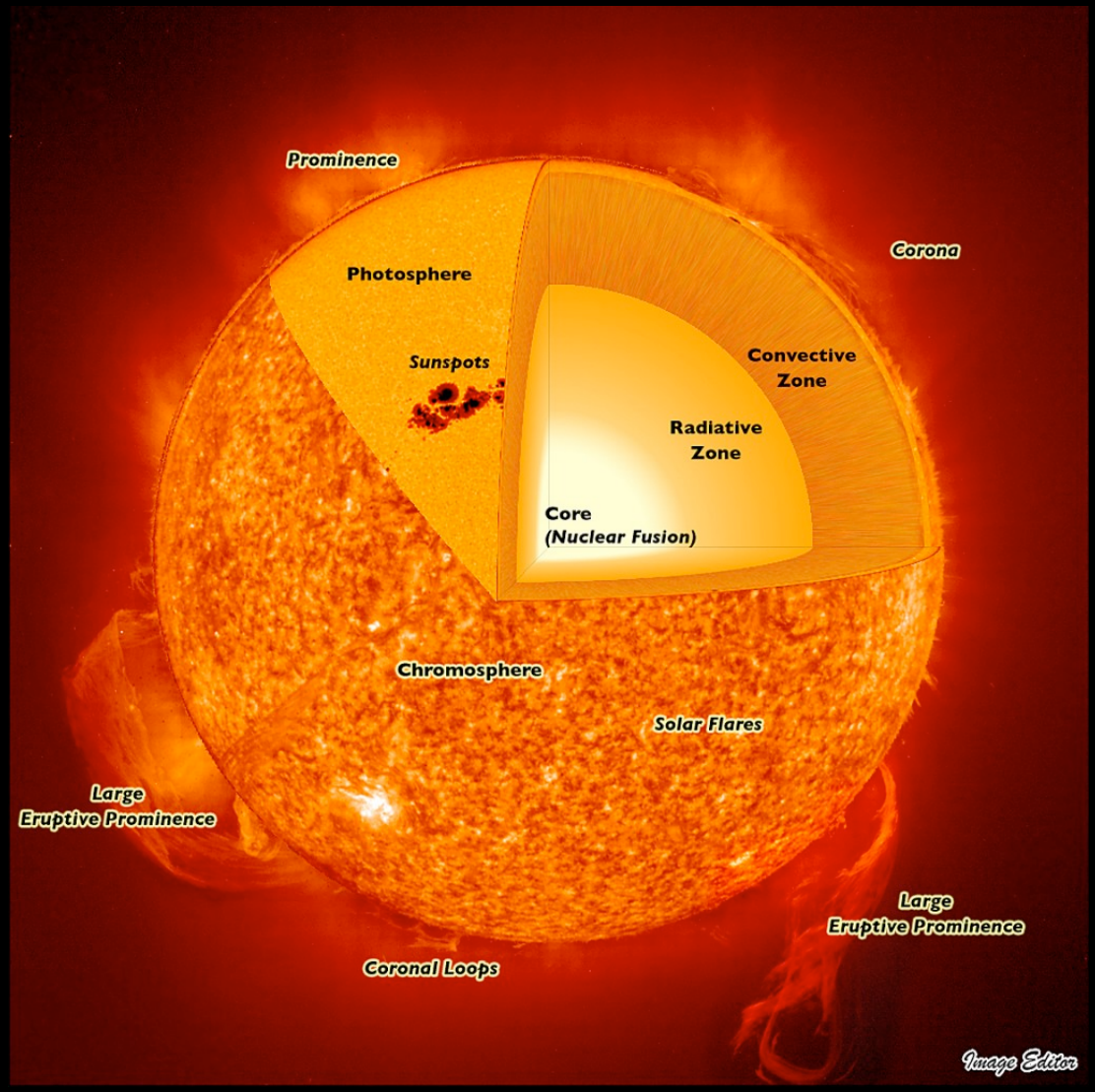

Vacuum insulator

Radiation conversion

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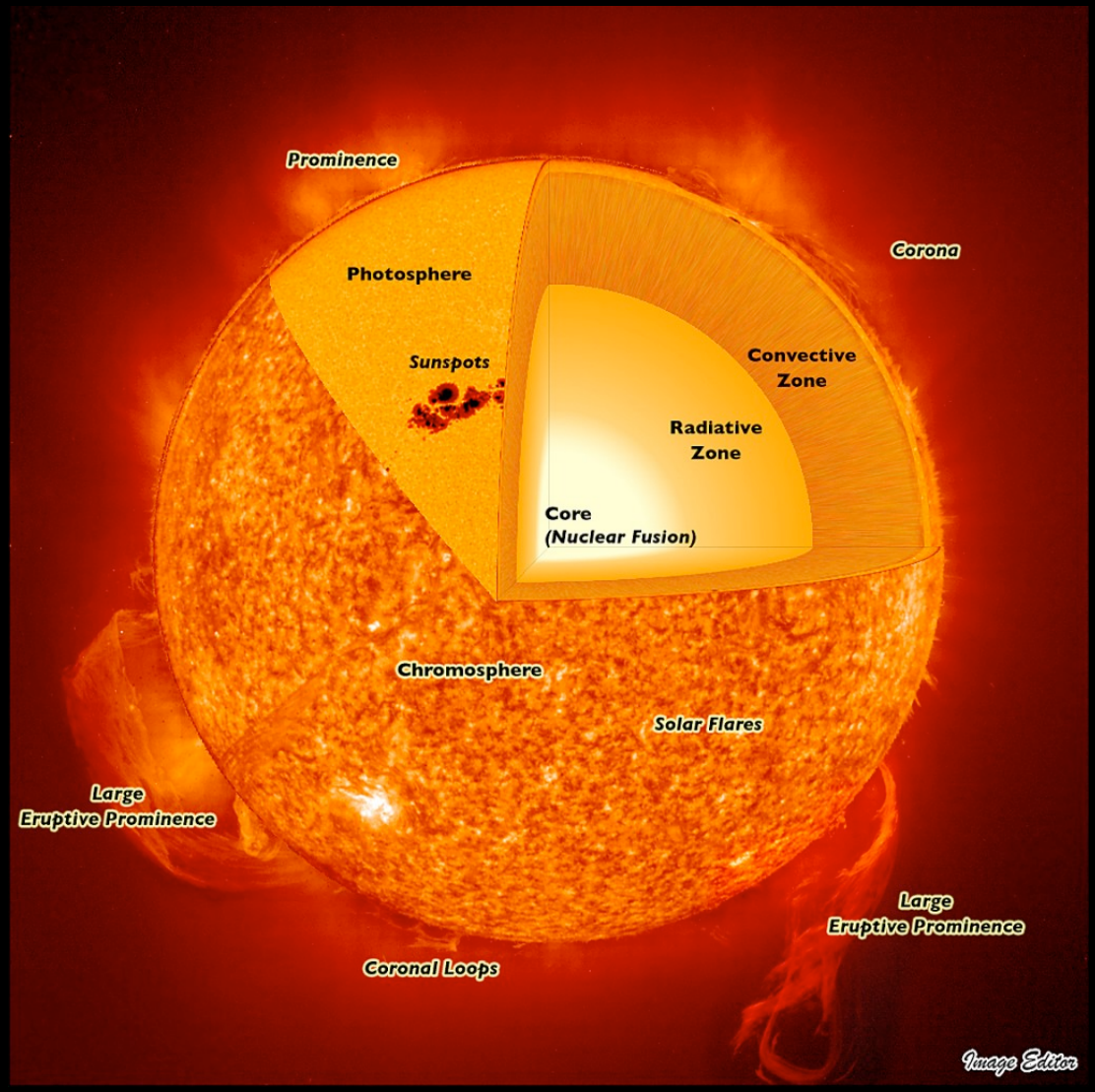

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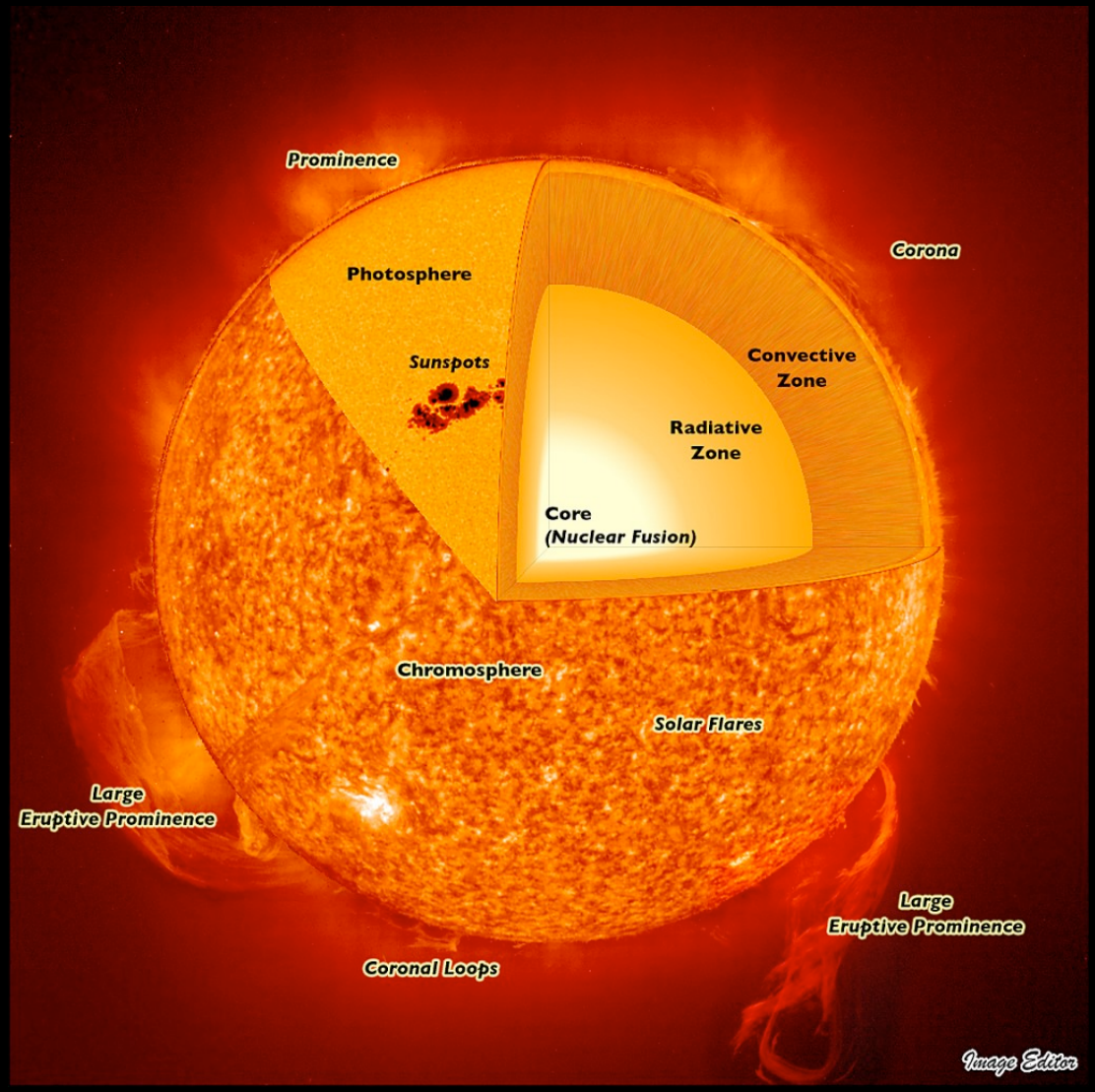

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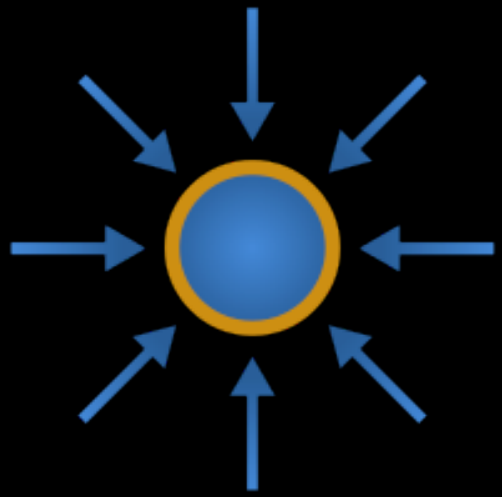
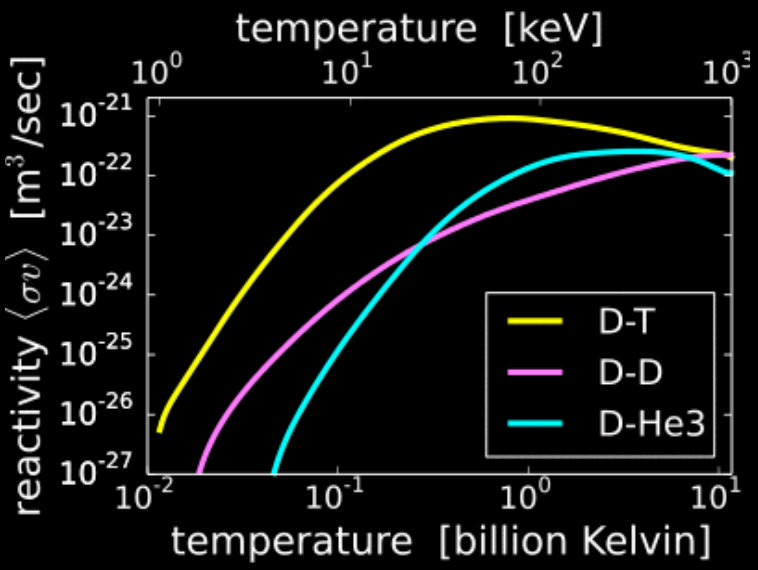
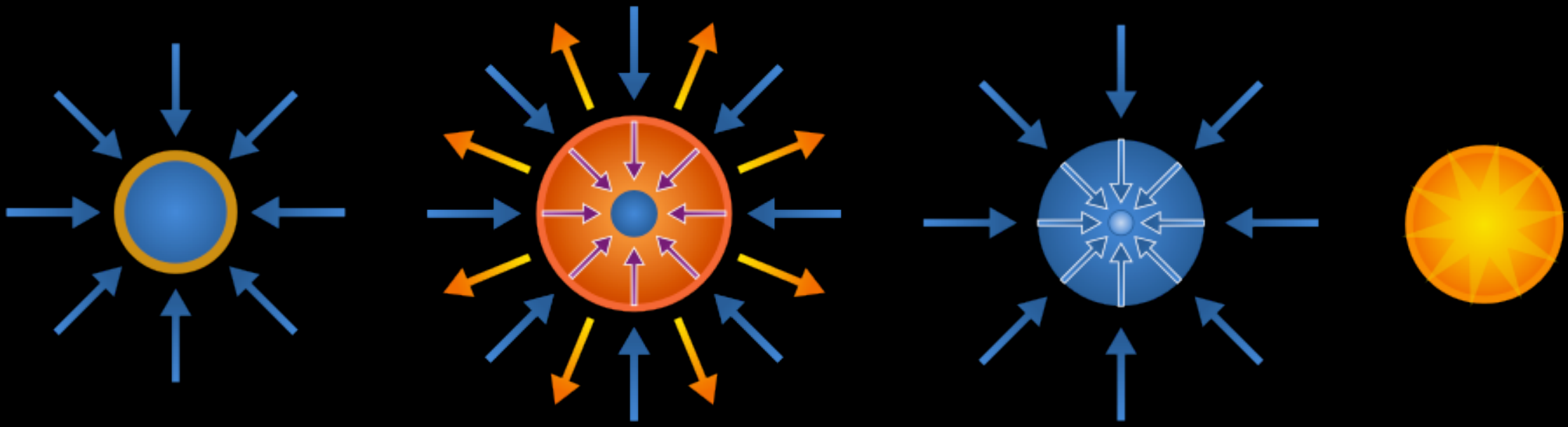
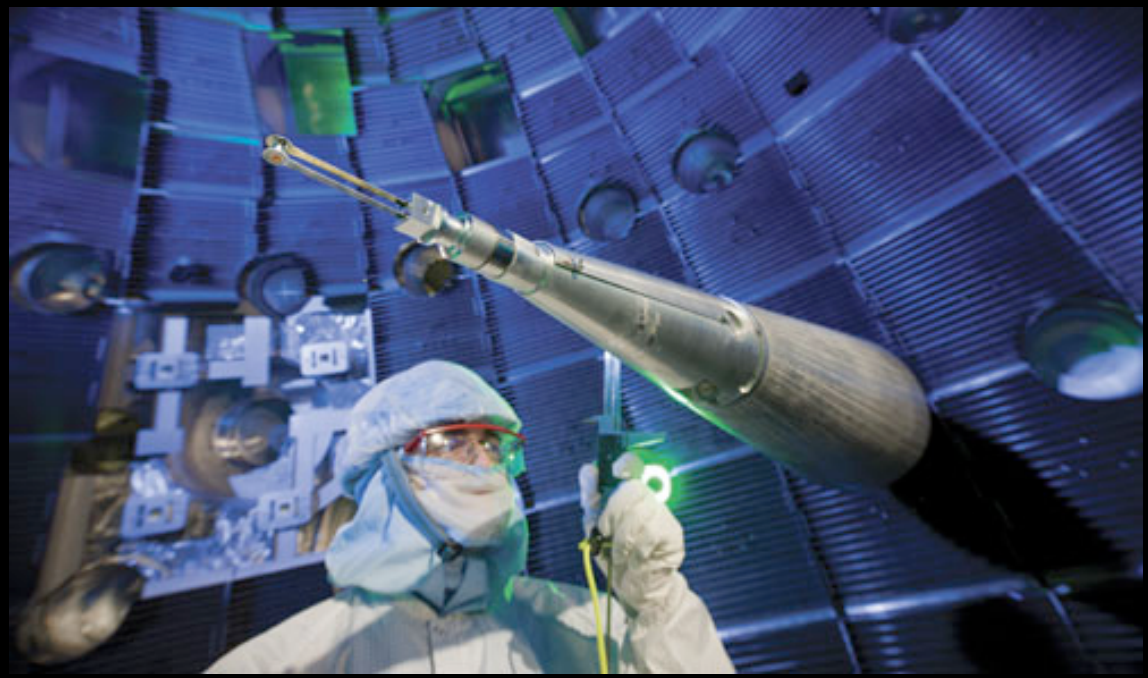




Can do this in a more controlled way using “inertial confinement” with lasers heating outer surface of a small DT sphere.





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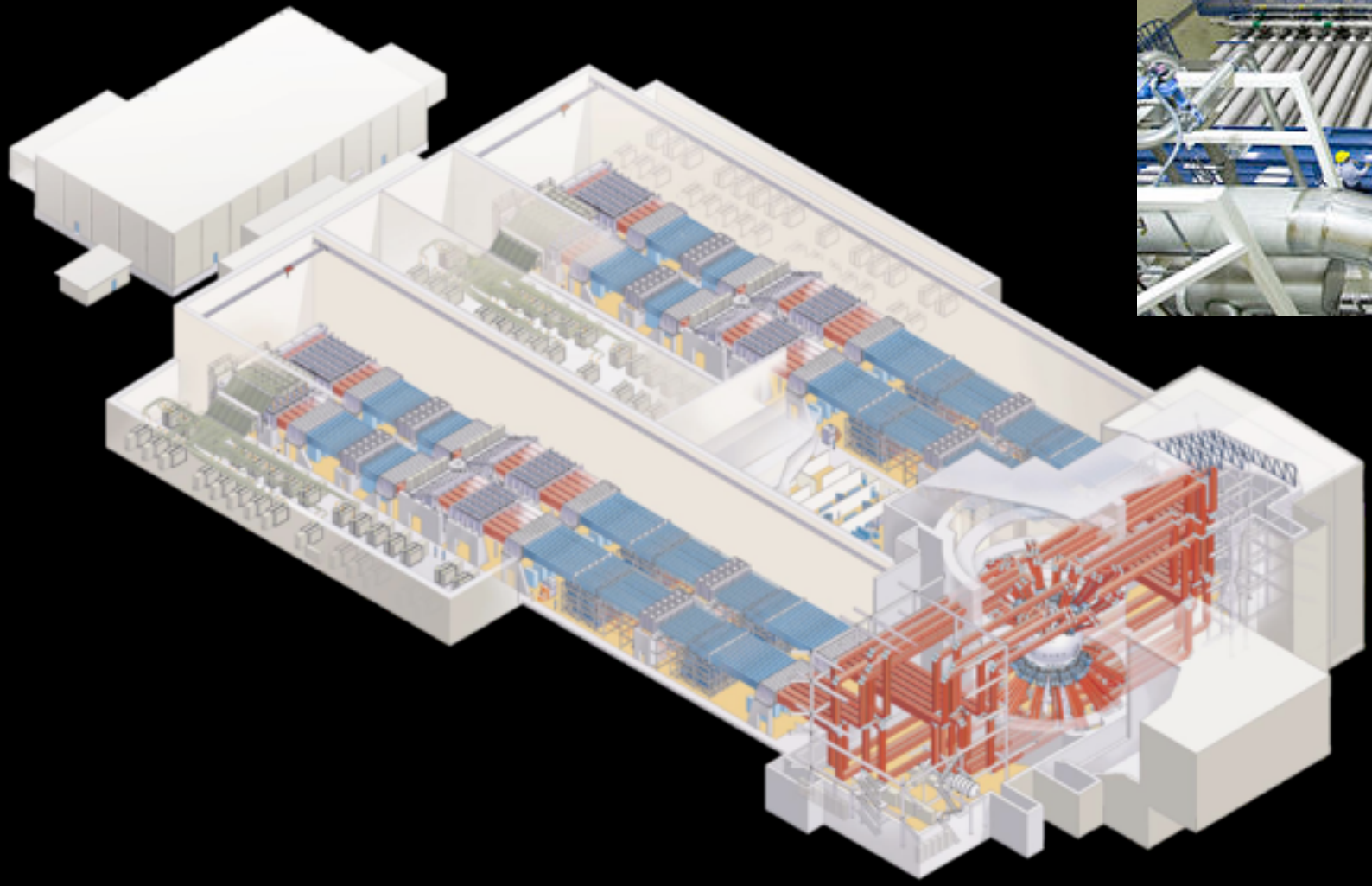

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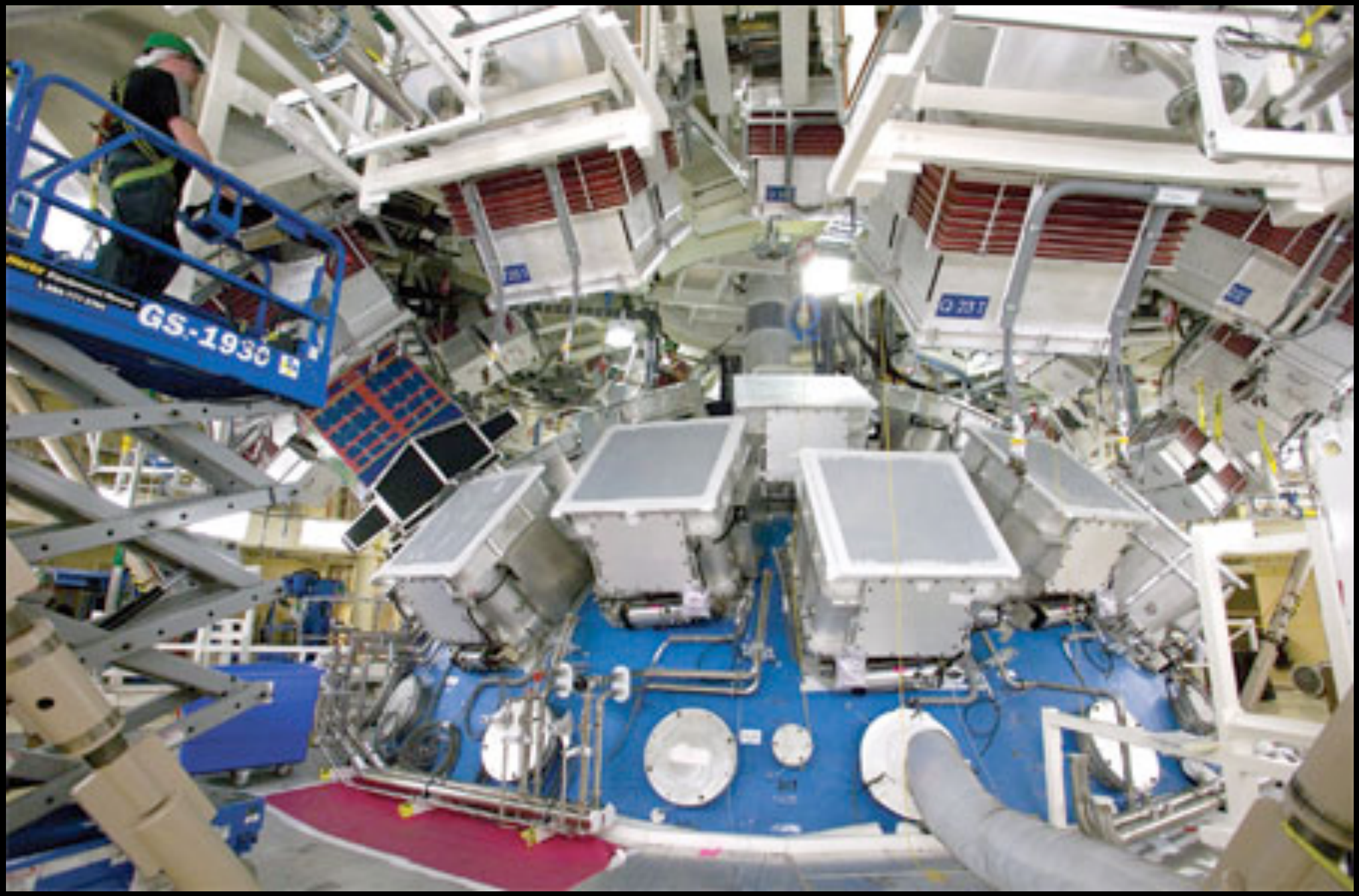

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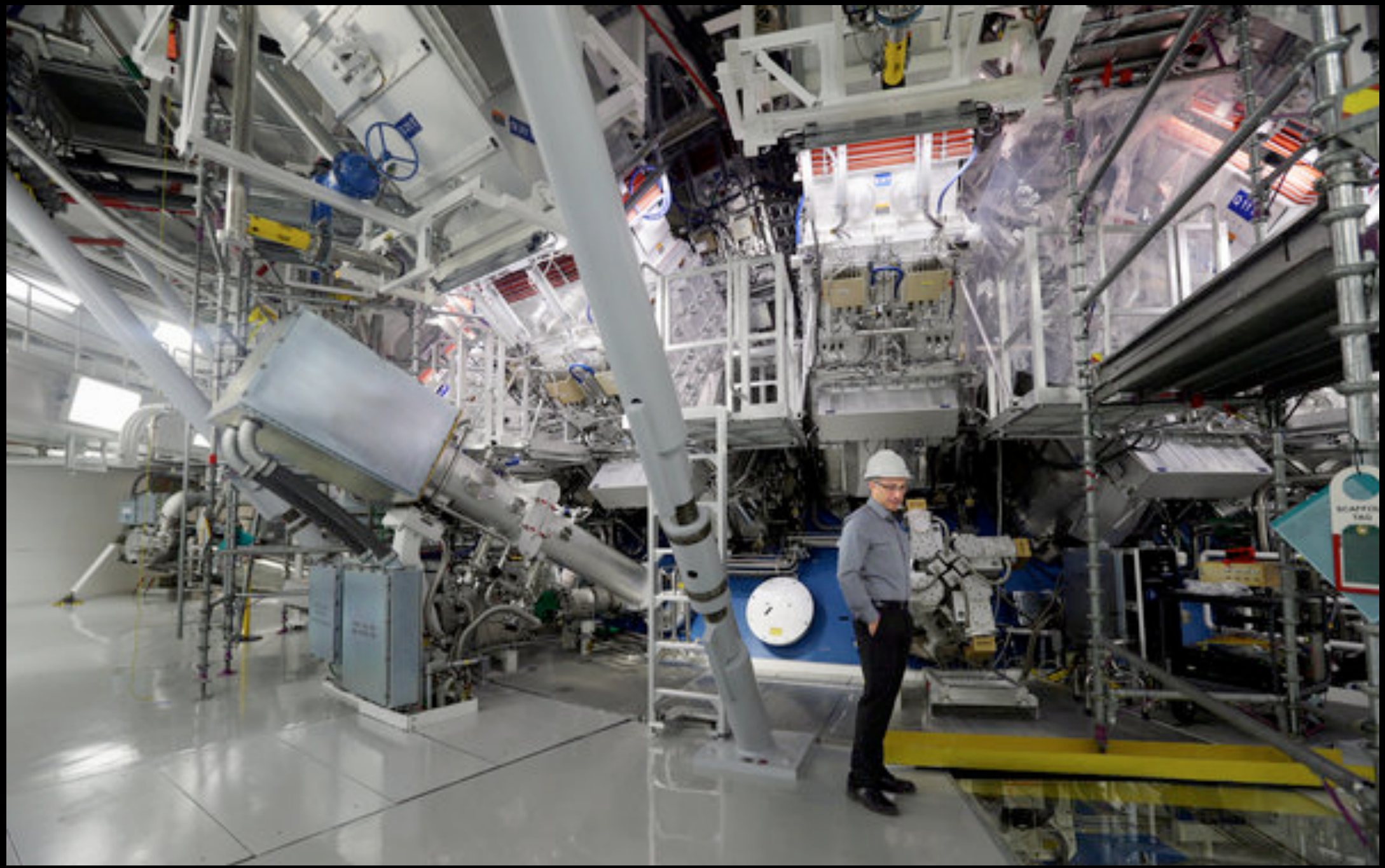

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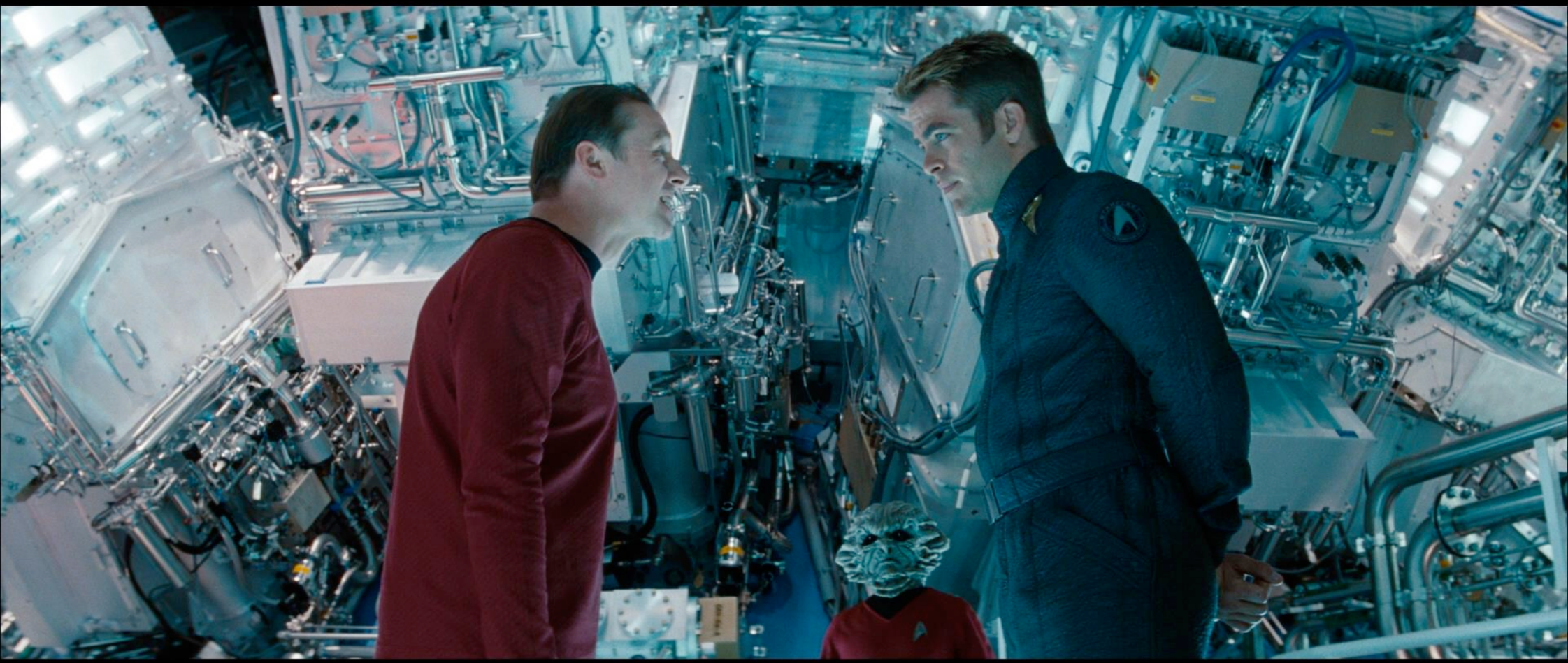

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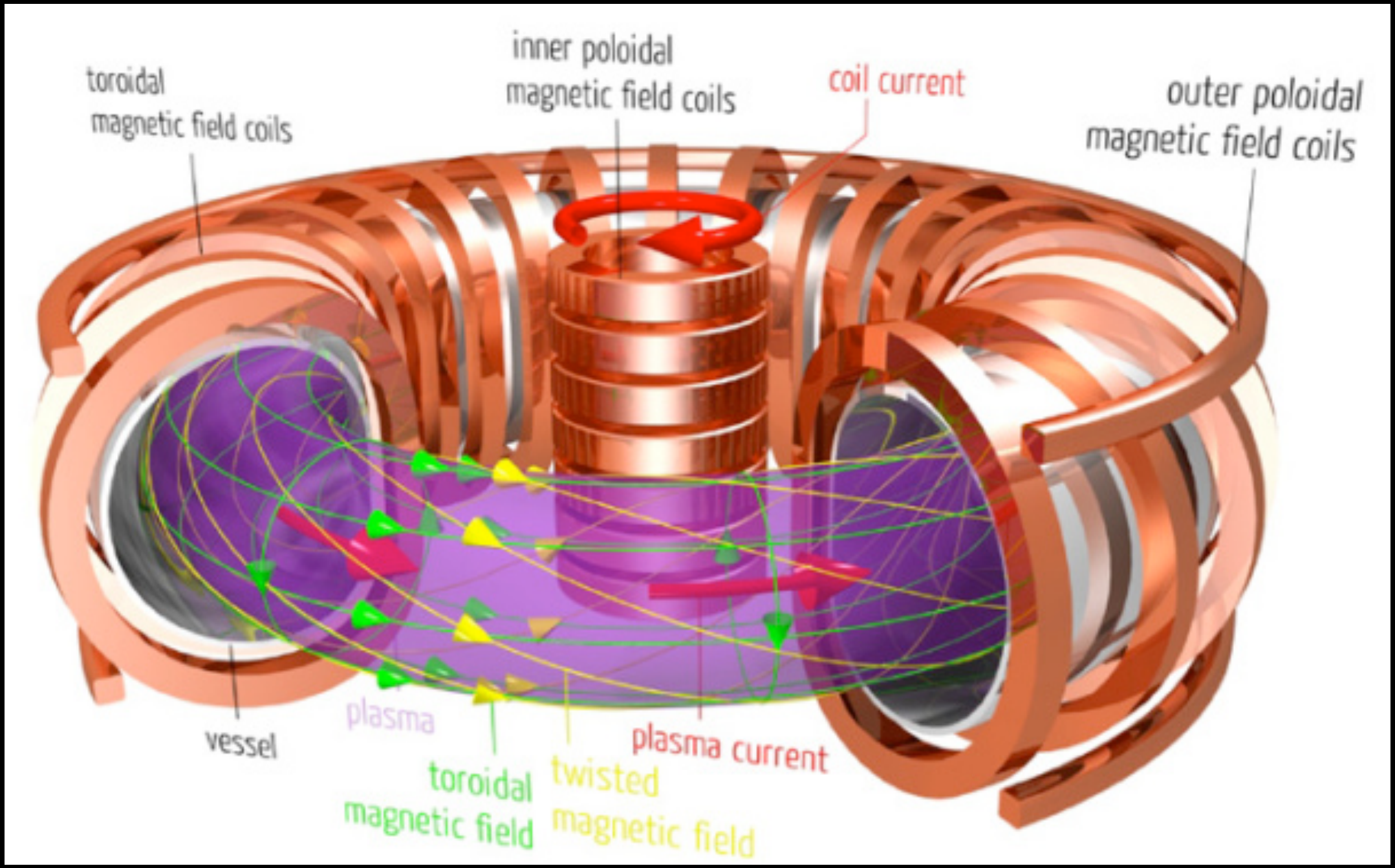
Comment on energy production vs “research”.

Can do this in a more controlled way using “magnetic confinement” with magnets holding a plasma away from the container.



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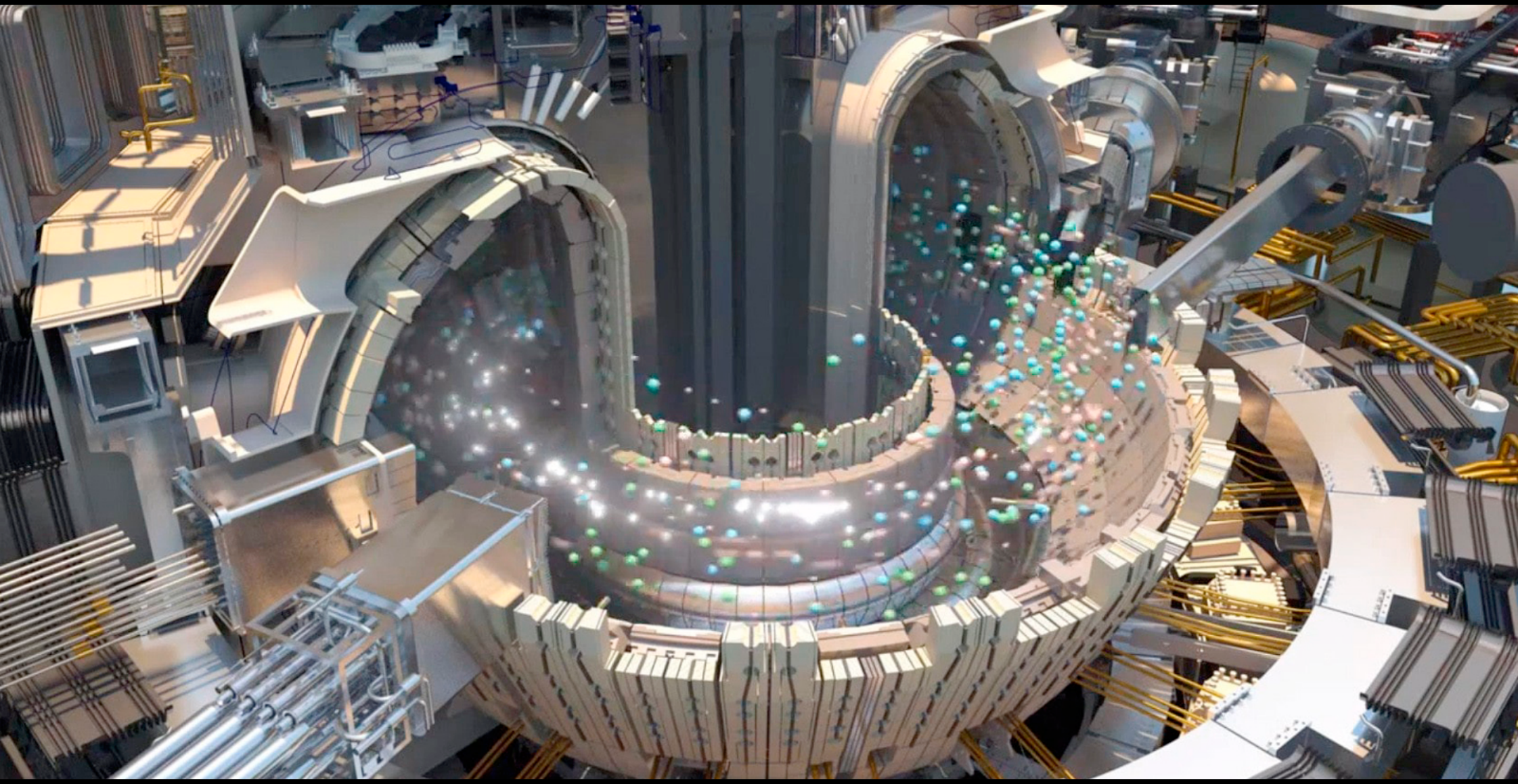

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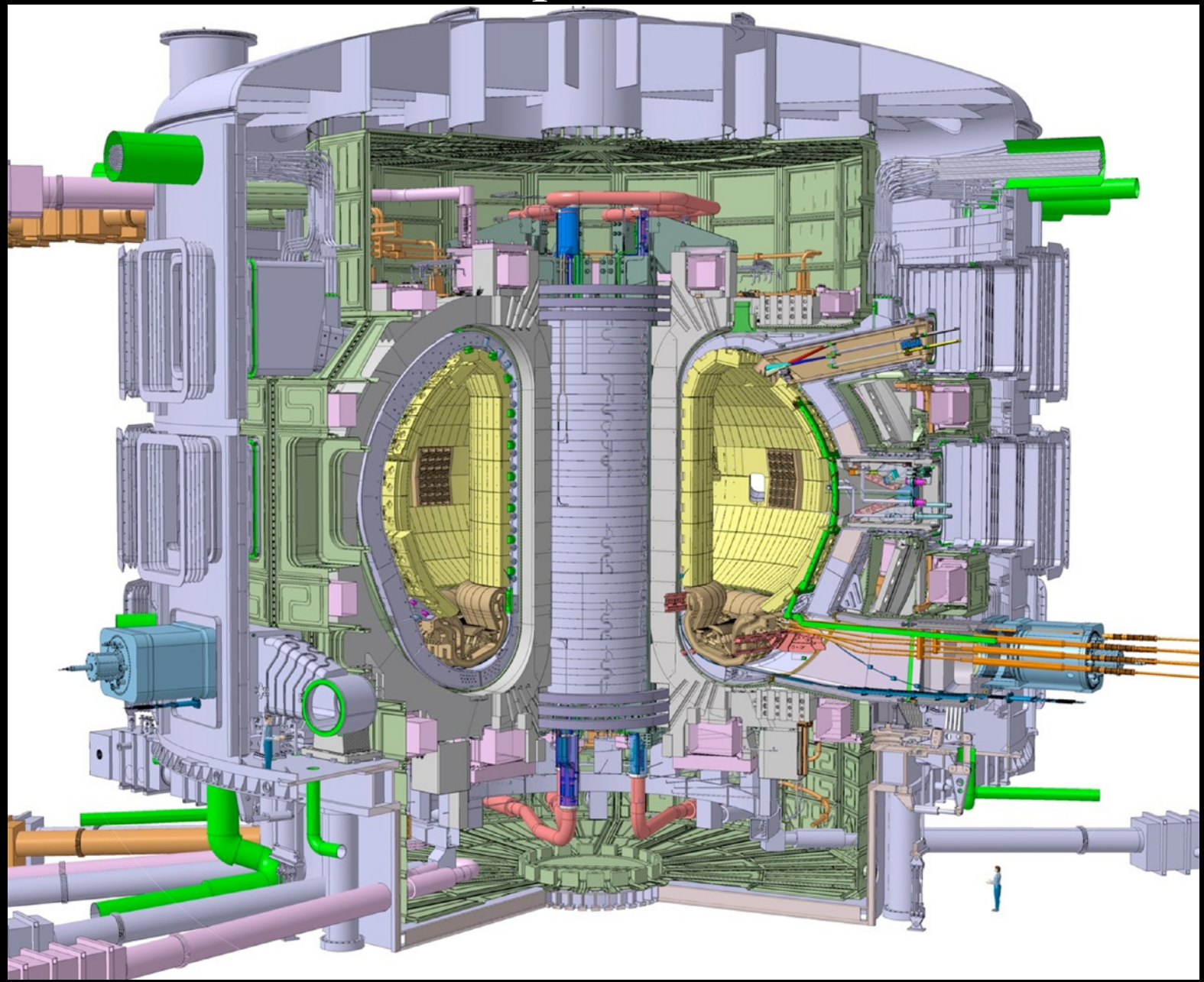
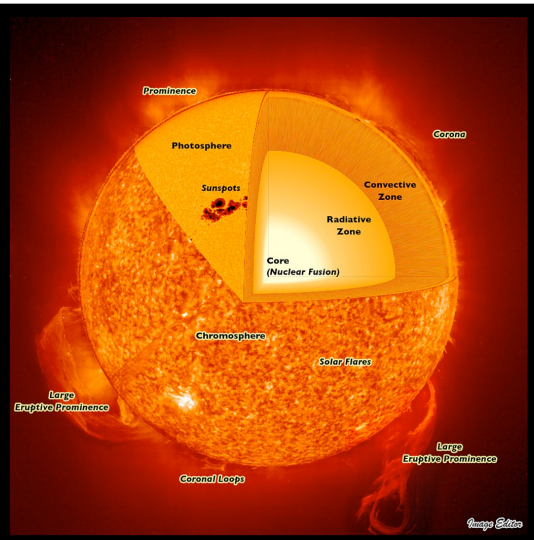
Can do this in a more controlled way using “magnetic confinement” with magnets holding a plasma away from the container.

ITER: International Experimental Tokomak Reactor



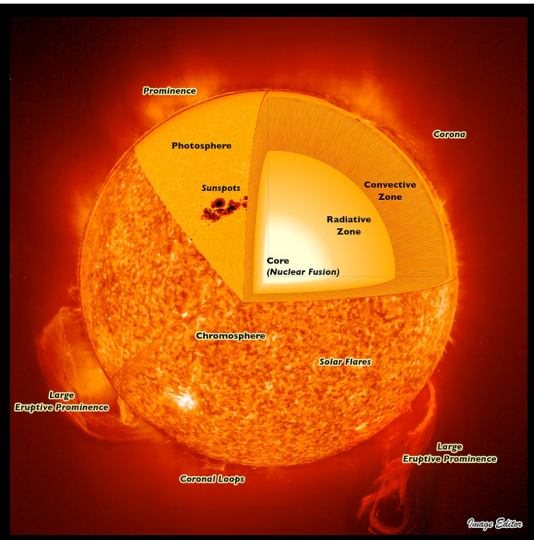
Extra material — A fusion powered car

Energy from fusion plant accumulated throughout a day and stored in a battery



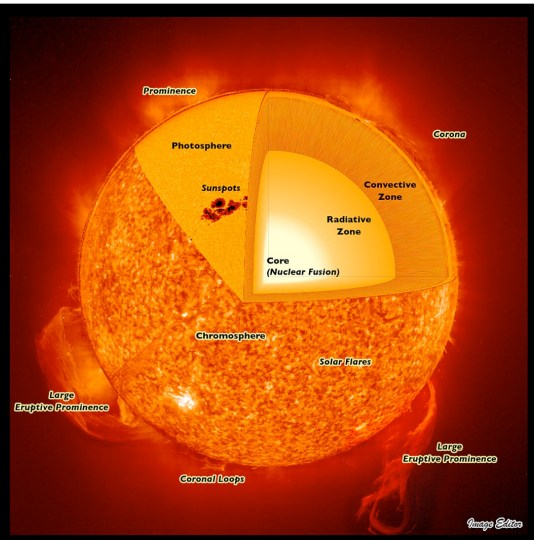
Extra material — A fusion powered car

Energy from fusion plant accumulated via photosynthesis over an eon and stored underground



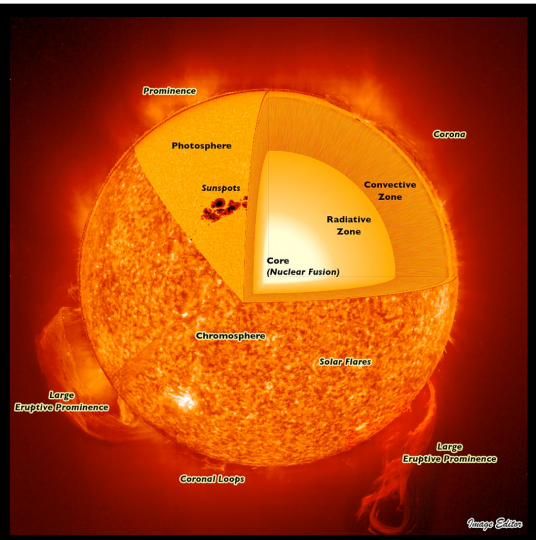
Extra material — A fusion powered car

Energy from fusion plant accumulated via photosynthesis over an eon and stored underground, pumped out, processed, trucked, pumped down, then up into tank.

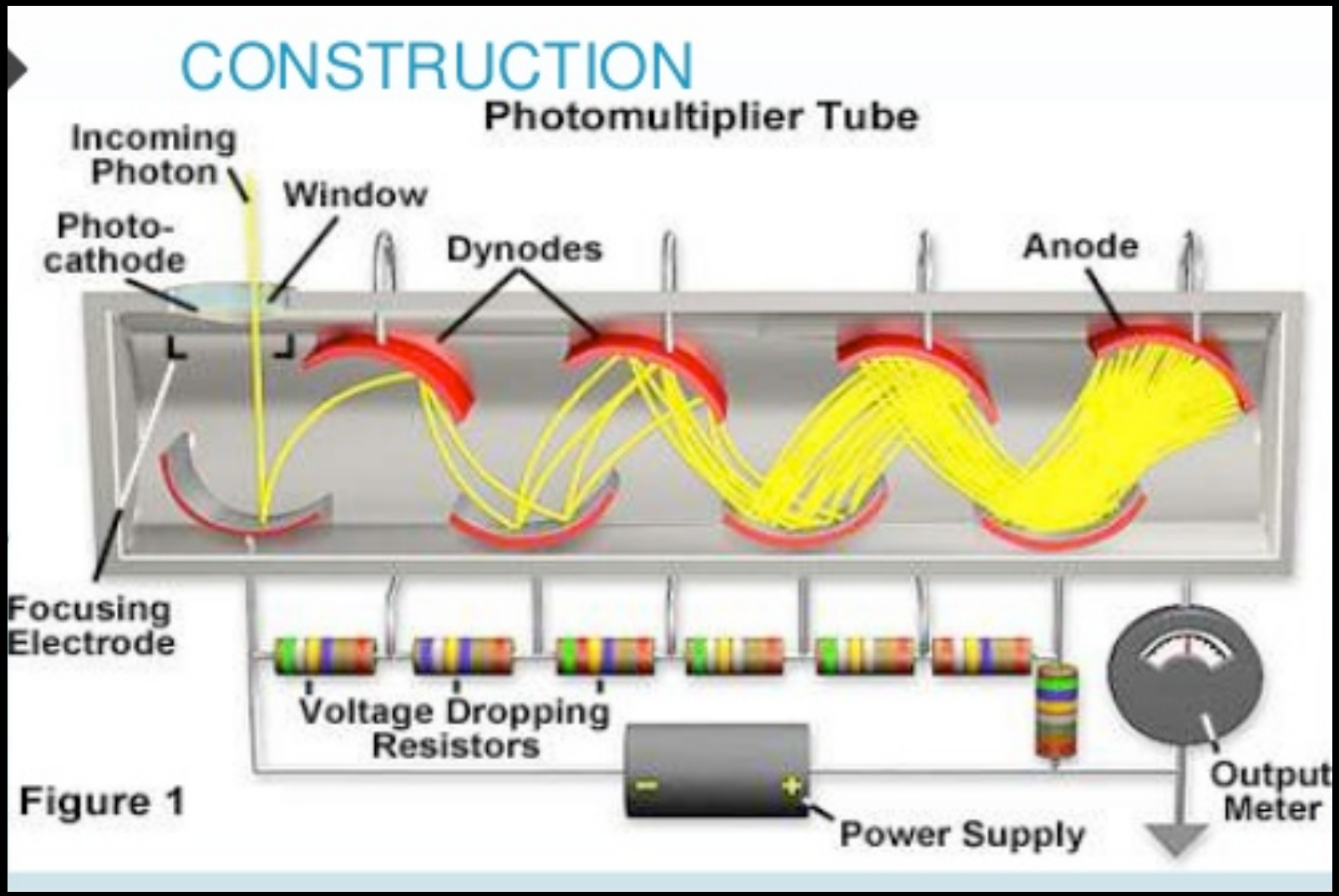


Extra material — A fusion powered car

Energy from fusion plant accumulated via photosynthesis over an eon and stored underground as coal, dug out, processed, shipped, burnt to generate electricity, transmitted, and stored in a battery



Extra material — how do those photodetectors work?



Extra material — how do those photodetectors work?