The Laser Turns 50: A Brief History and New Frontiers

Recipe for a laser-made star:

How lasers can enable us to harness star power for a clean energy future

Ted Feldman

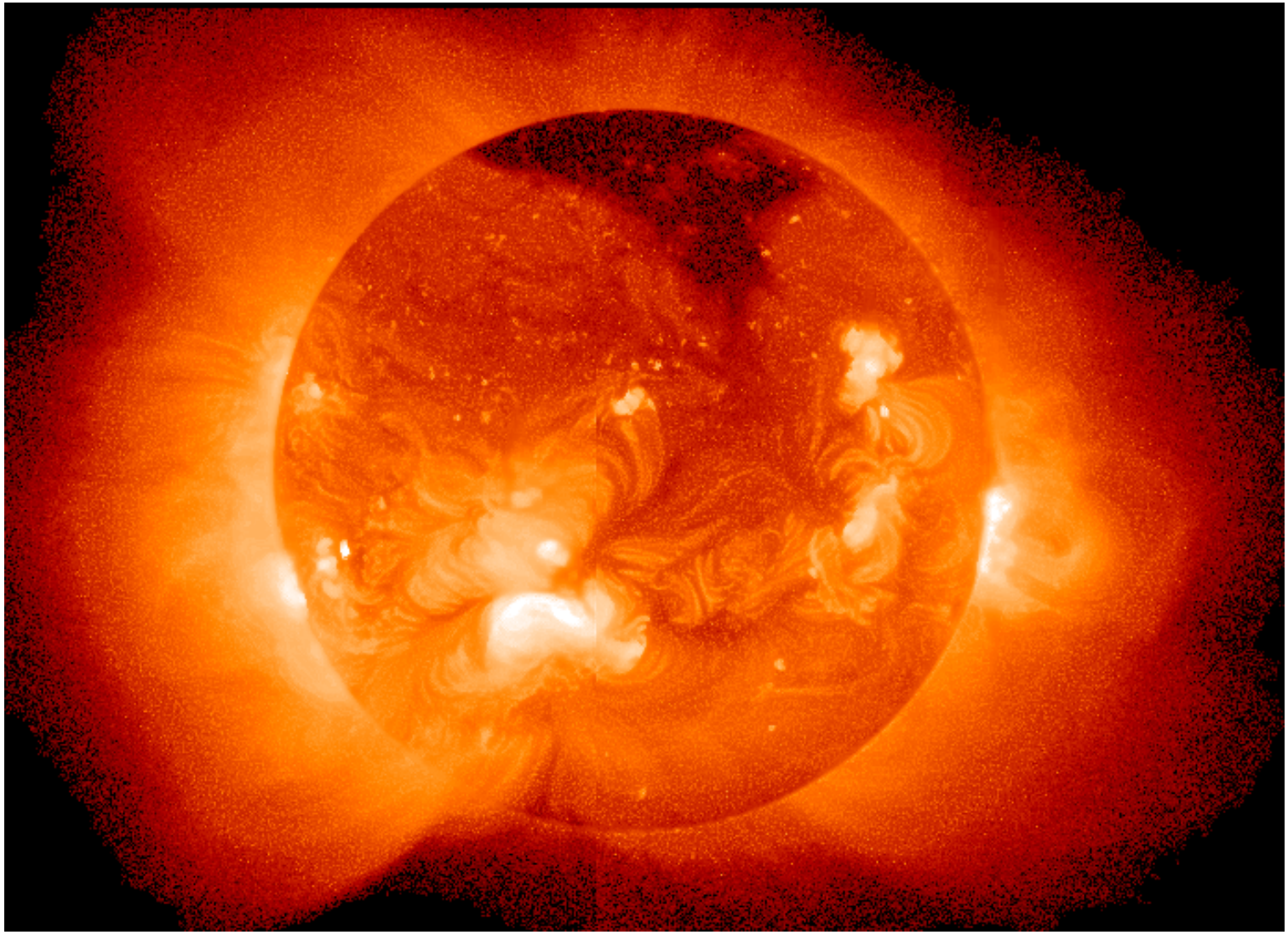
We need energy alternatives to fossil fuels

Wikimedia Commons User: M. D. Wilson

A Present Alternative: Nuclear Fission

Wikimedia Commons User: S. Kuhn

Nuclear Fusion: An old recipe for clean energy



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Nuclear Fusion: An old recipe for clean energy

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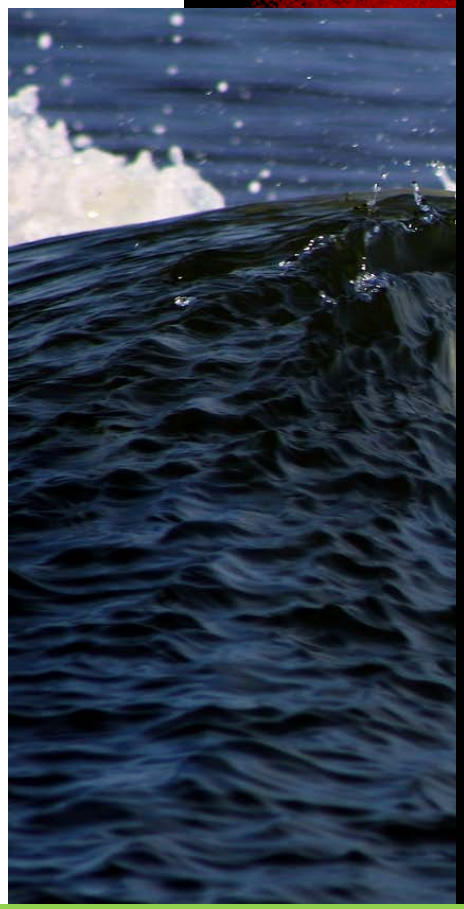
Nuclear Fusion: An old recipe for clean energy



The Grand Challenge: Make this work on Earth

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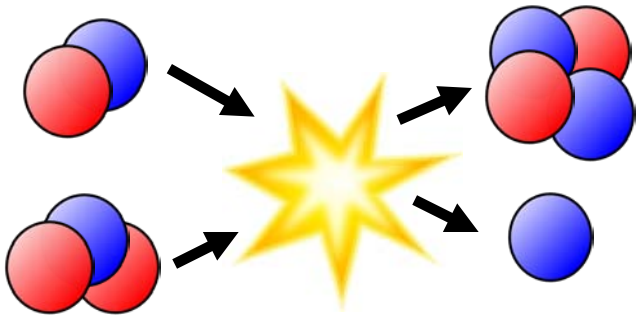
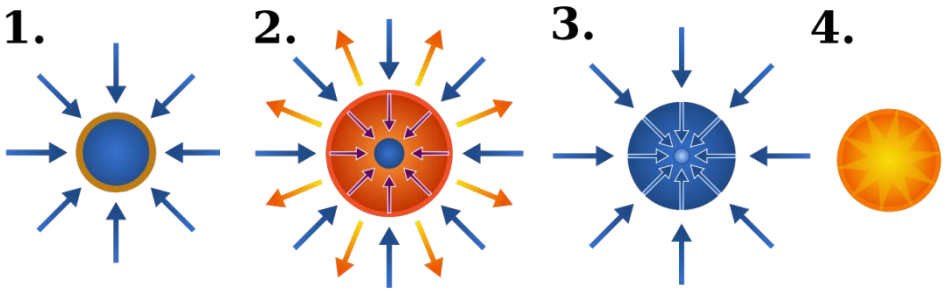
Recipe for a star

I. The Ingredients



II. The Preparation



III. Tools of the Trade

IV. Toward Clean Energy & Beyond

"Deuterium-Tritium fusion diagram," http://en.wikipedia.org/wiki/Nuclear_fusion (modified).
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Aerial photo of NIF credit: Lawrence Livermore National Laboratory
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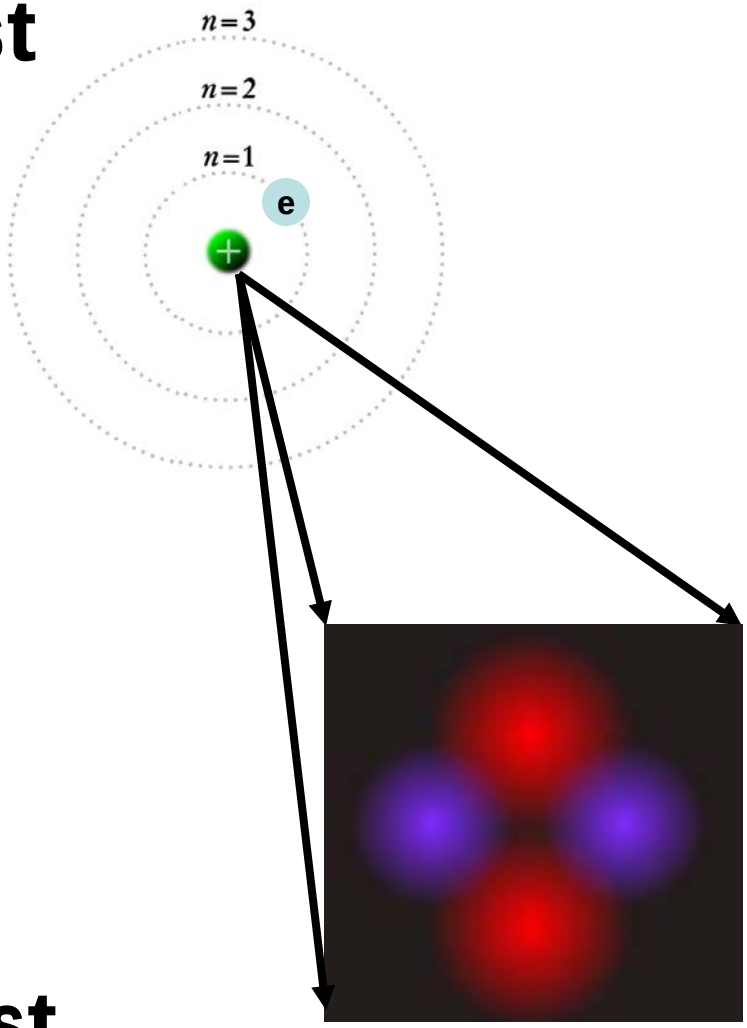
I. The Ingredients of Star Power

The basic ingredients of fusion

Largest



Smallest

Atoms:

nucleus **+** ***electrons***

Atomic Nuclei:

protons **+** ***neutrons***

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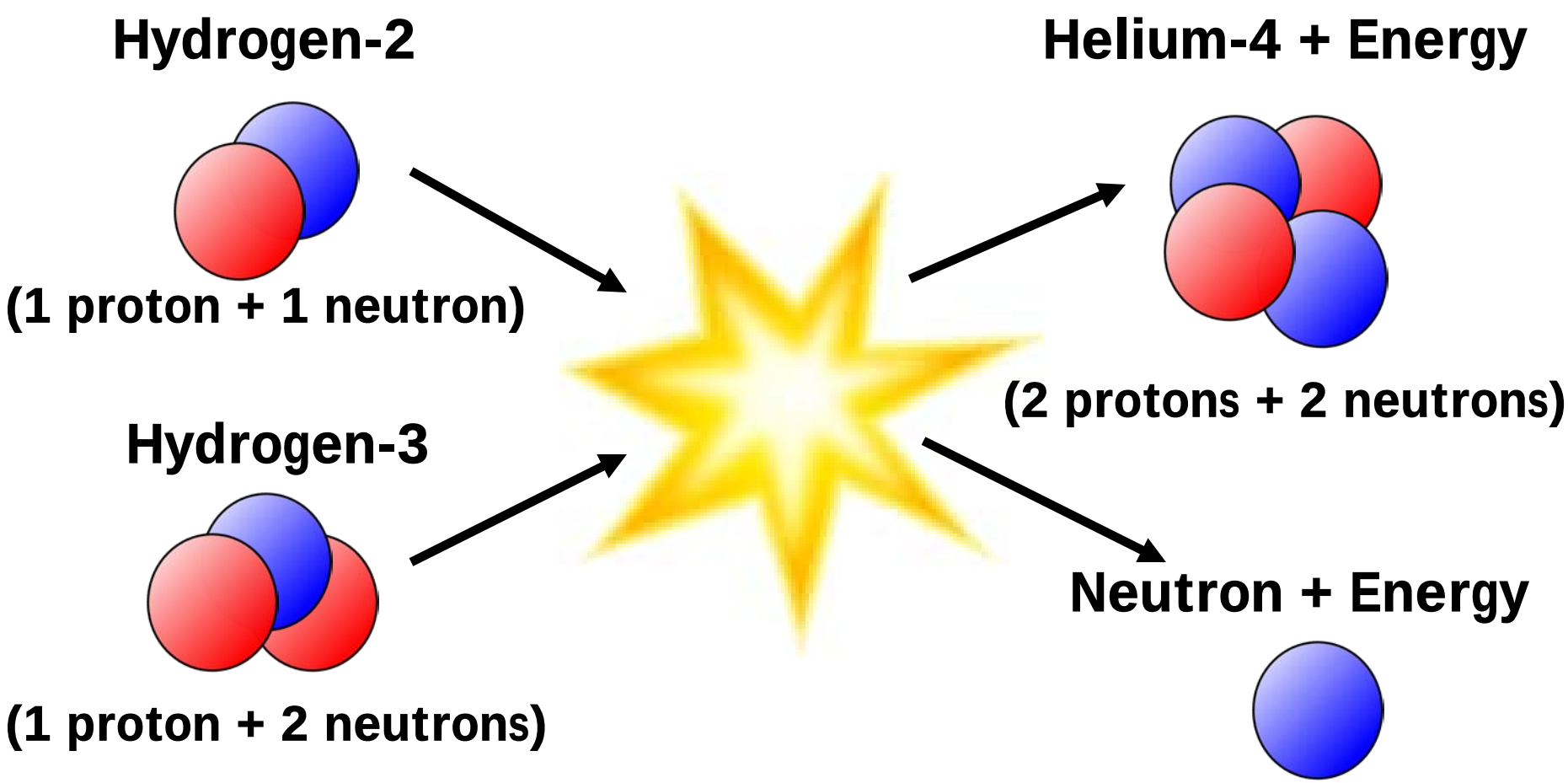
Nuclear Fusion: Combining Atomic Nuclei



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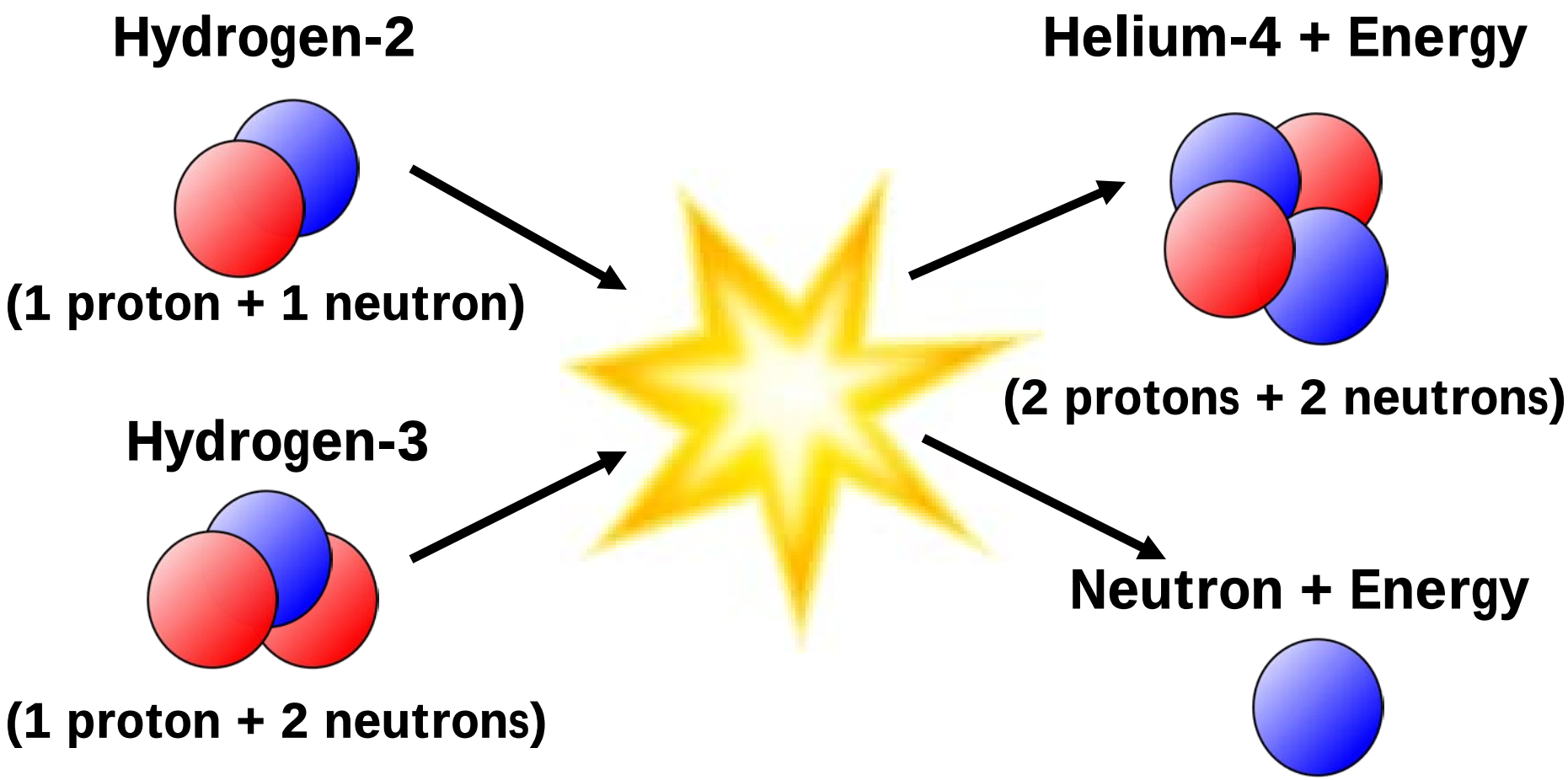
Why does fusion produce energy?



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E=mc2 Sculpture Image Credit: L. Schulz
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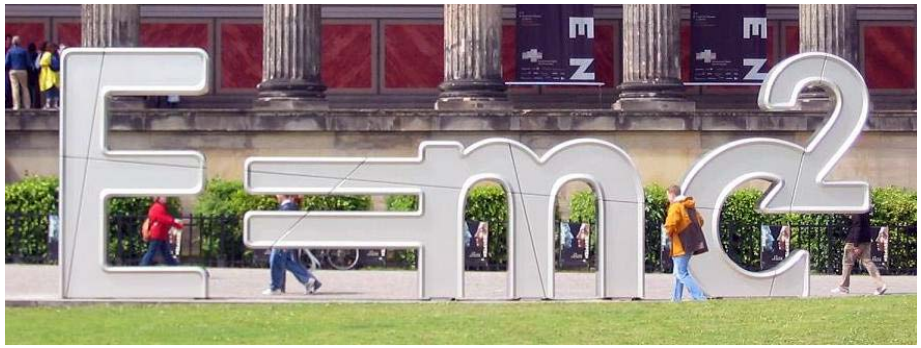

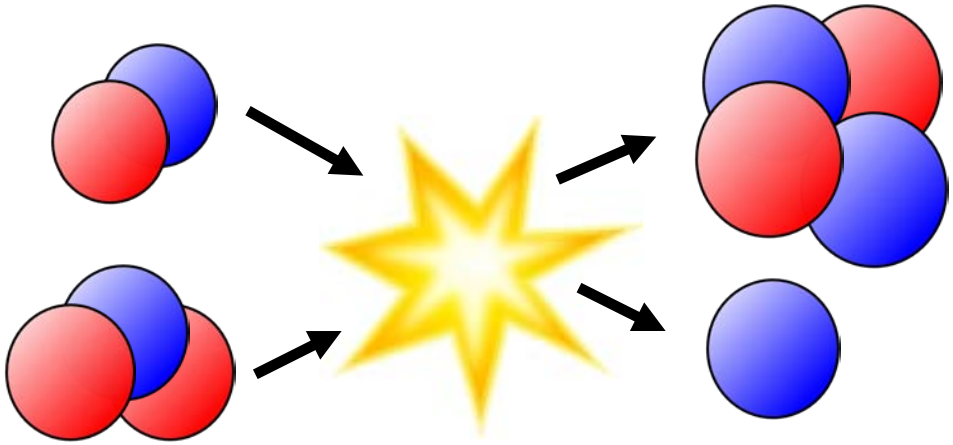

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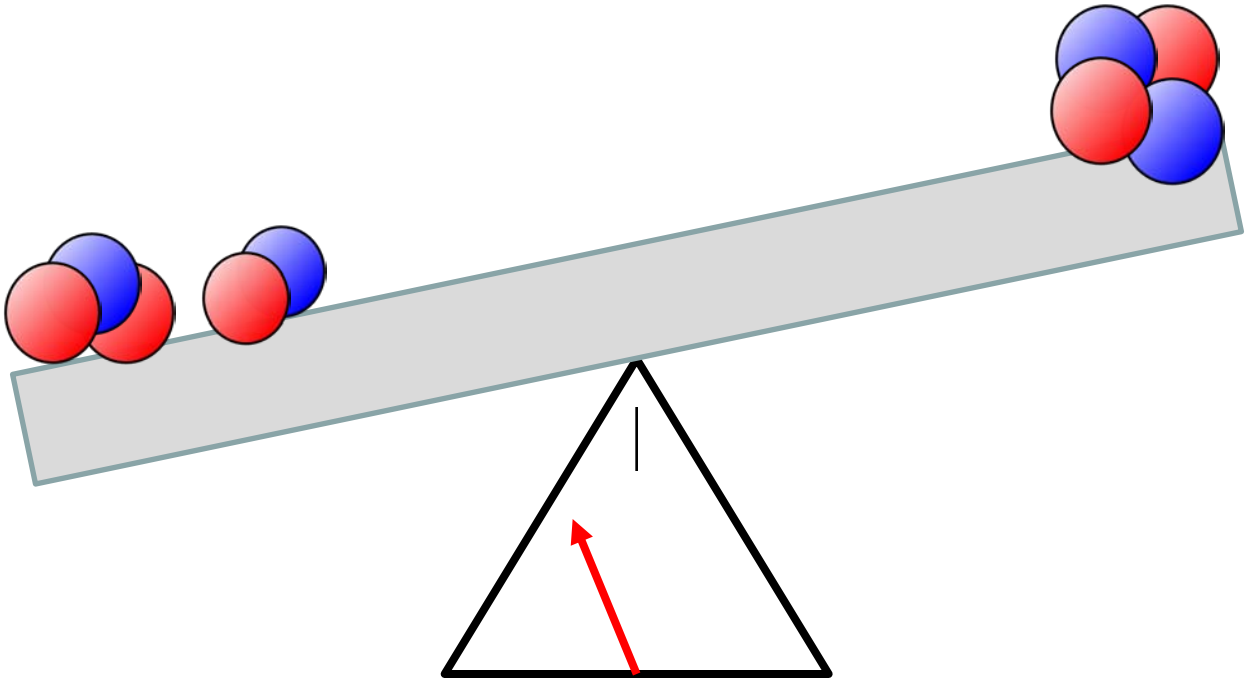

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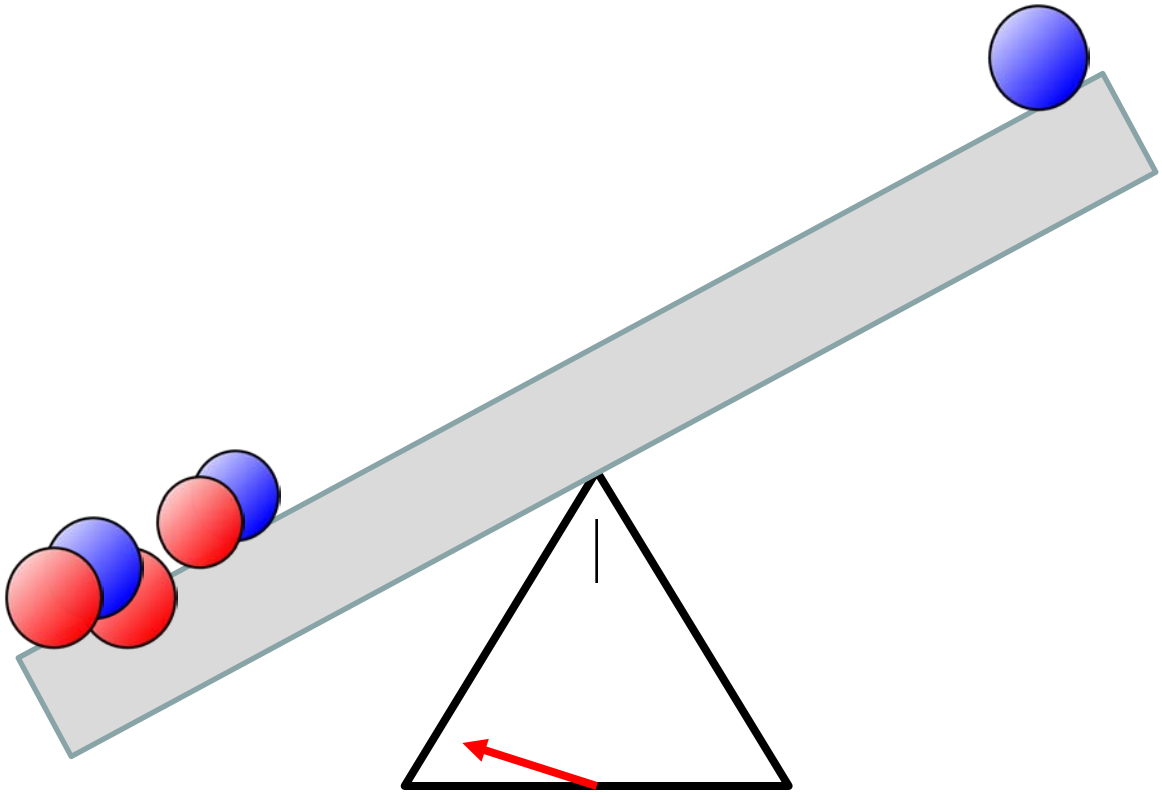
Why does fusion produce energy?



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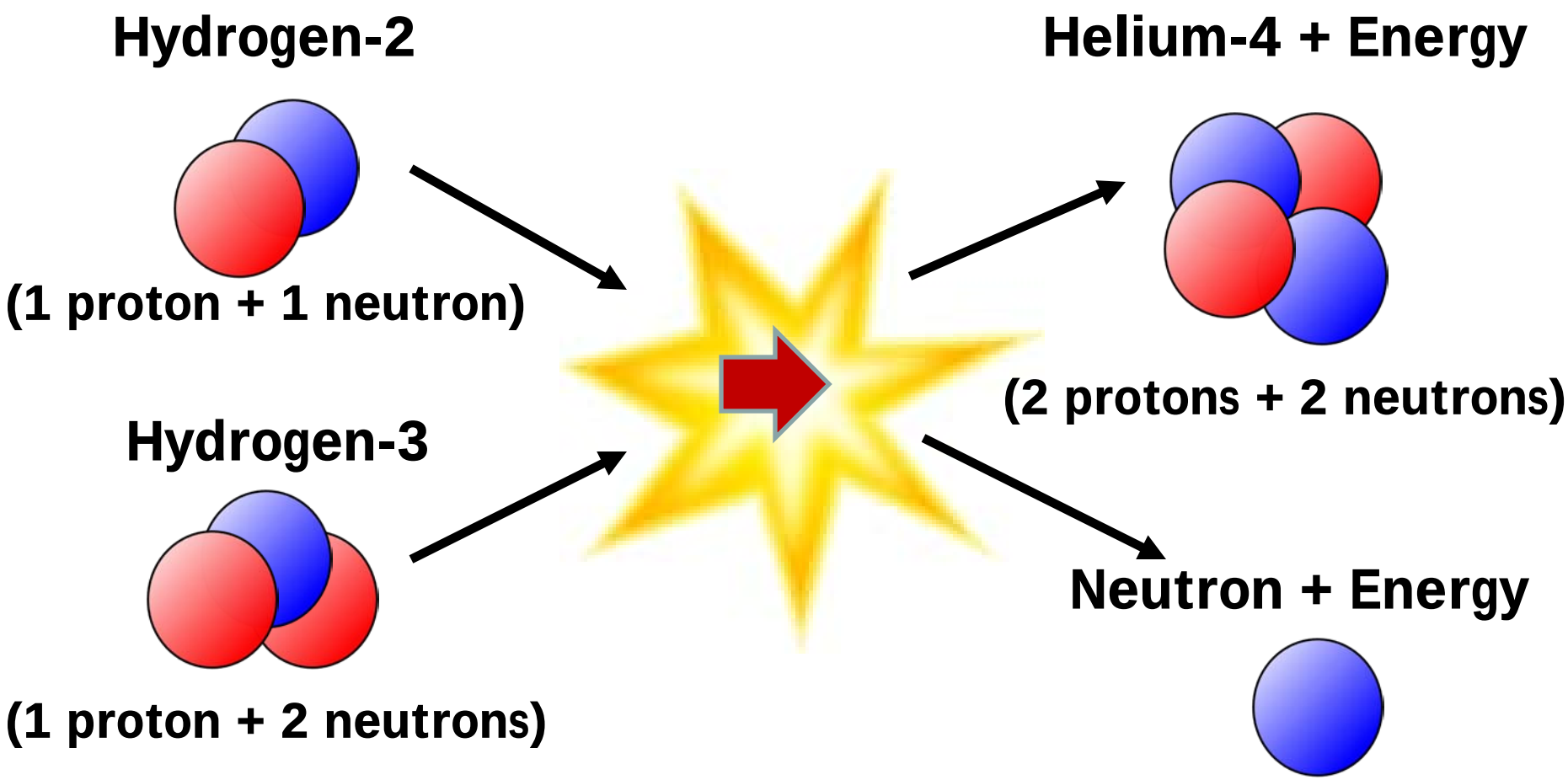
Fusion Diagram Credit: ikimedia Commons, "Deuterium-Tritium fusion diagram," http://en.wikipedia.org/wiki/Nuclear_fusion.

II. The Preparation

Sufficient ingredients to achieve ignition



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Sufficient ingredients to achieve ignition

1. Enough Fuel

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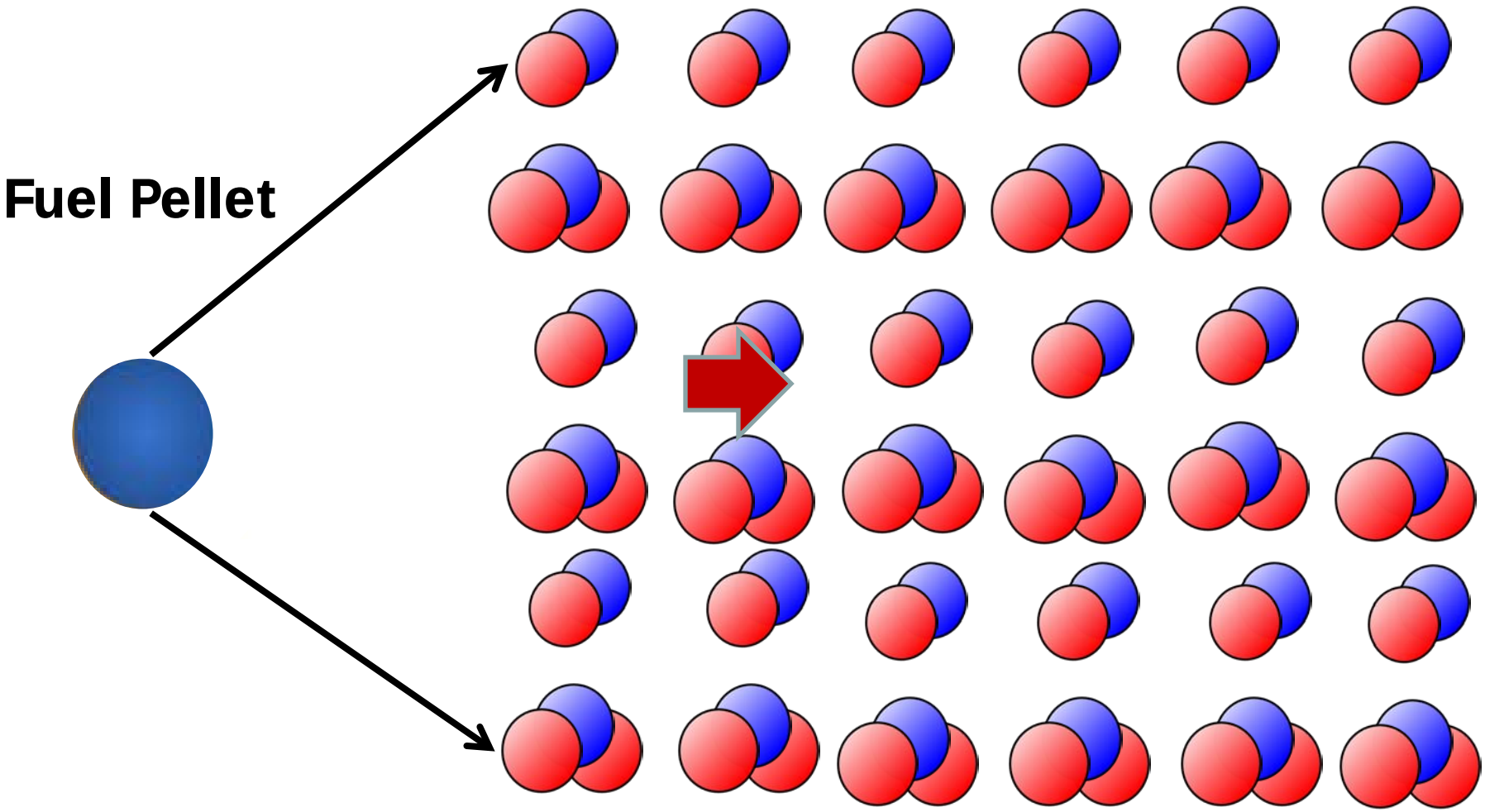
Sufficient ingredients to achieve ignition



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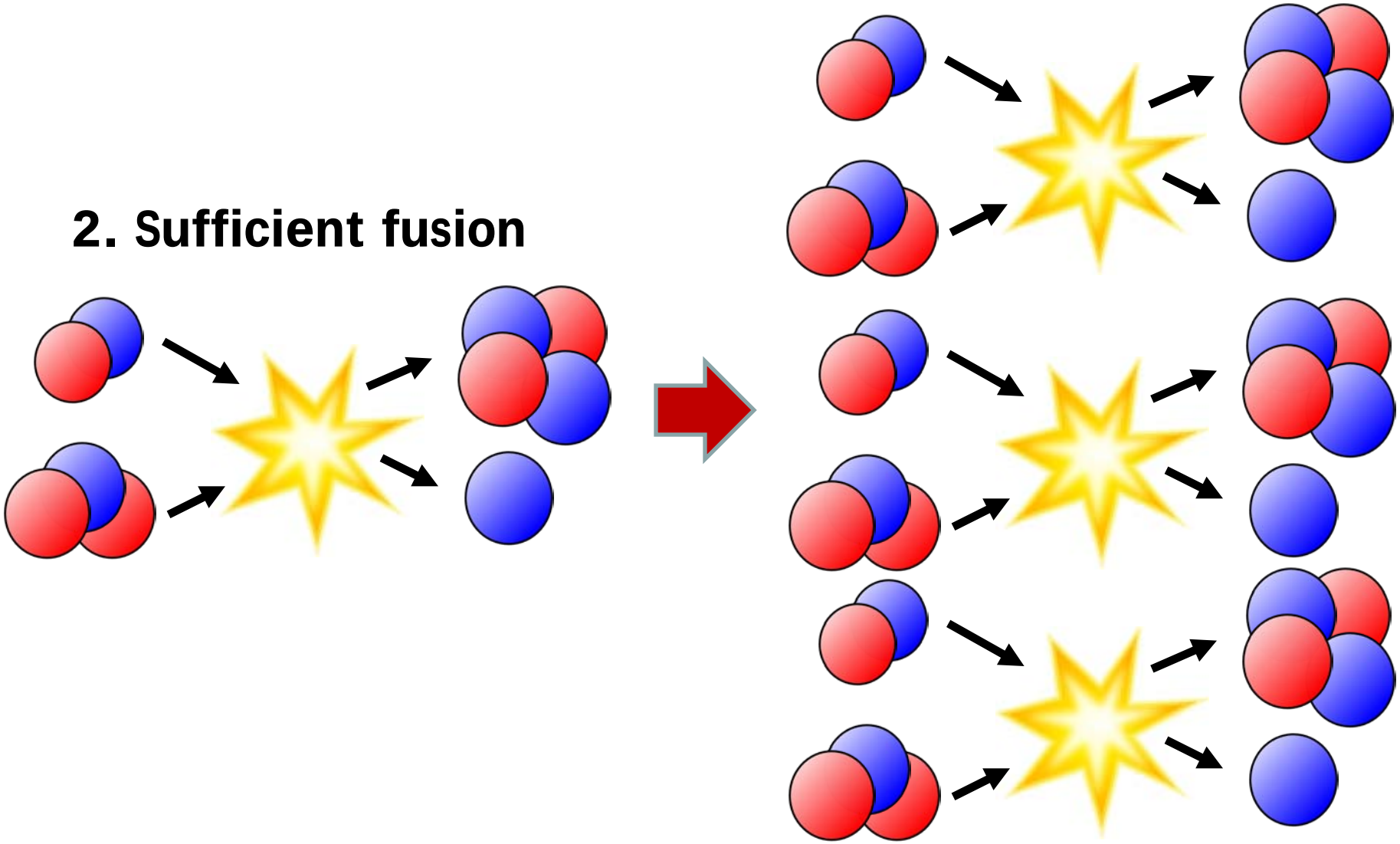
Sufficient ingredients to achieve ignition

2. Sufficient fusion



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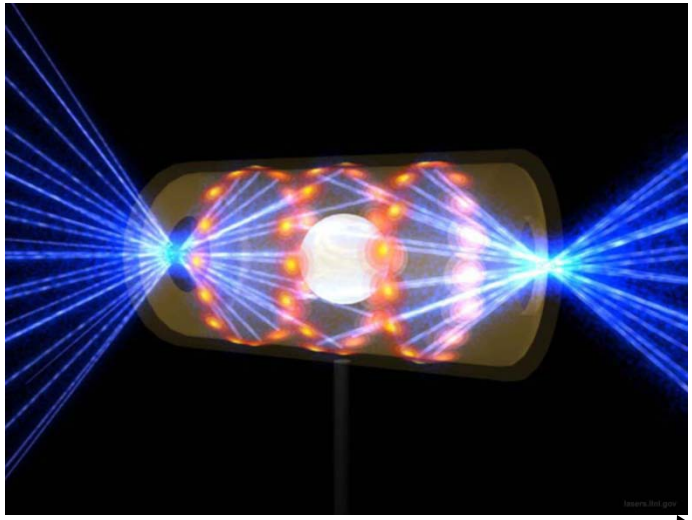
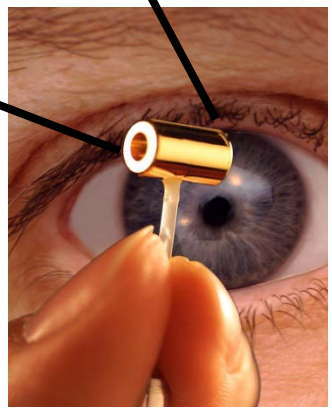
Laser energy initiates fusion



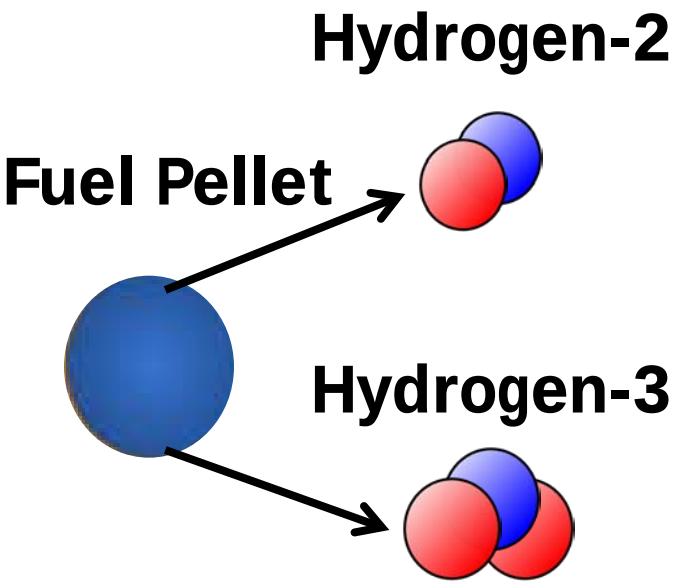
Intense laser beams heat the surface of the target



All of this happens in a tiny capsule called a *hohlraum* which contains a tiny amount of fusion fuel.

NIF Hohlraum Image Credits: Lawrence Livermore National Laboratory

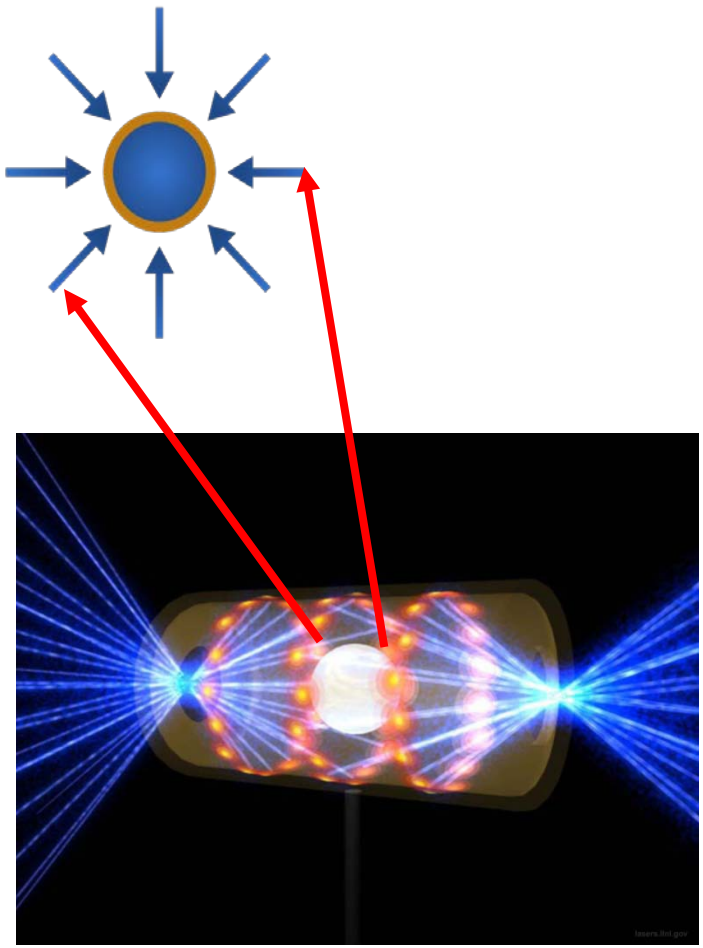
The pathway to ignition



Hohlraum Image Credit: Lawrence Livermore National Laboratory. Apollo 15 Launch Image Credit: NASA. Wikimedia Commons User: B. D. Esham (ignition cycle, modified). Wikimedia Commons, "Deuterium-Tritium fusion diagram," http://en.wikipedia.org/wiki/Nuclear_fusion. (modified)

The pathway to ignition

Heat Target



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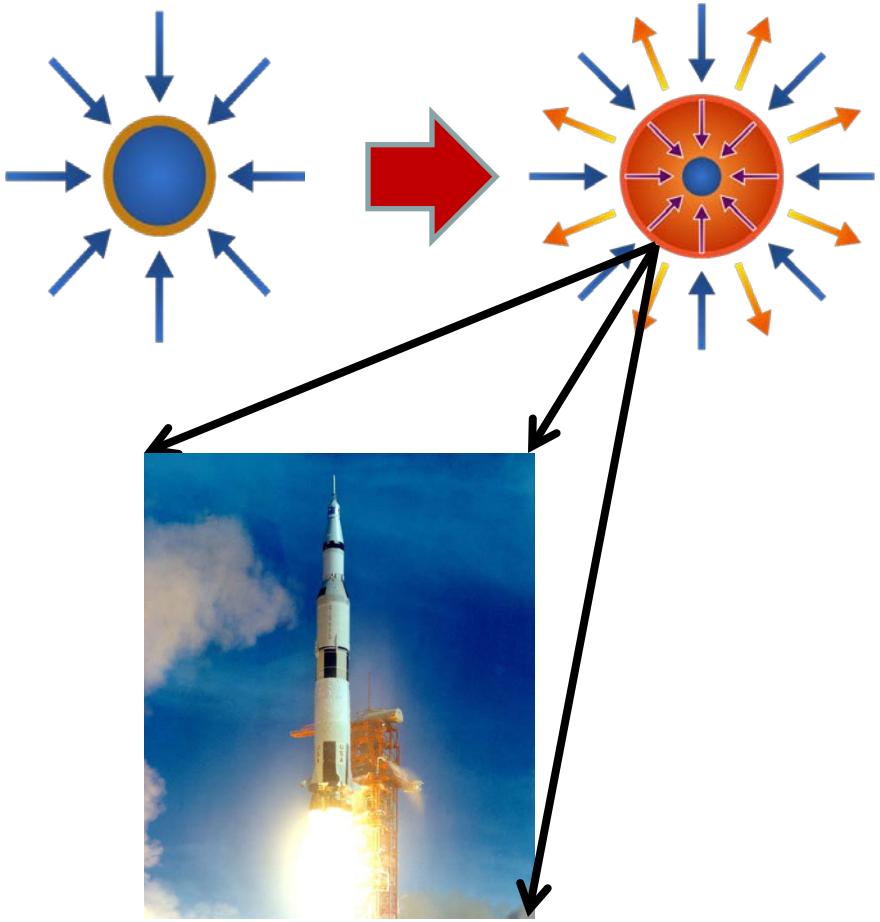
The pathway to ignition

Heat Target **Compression**



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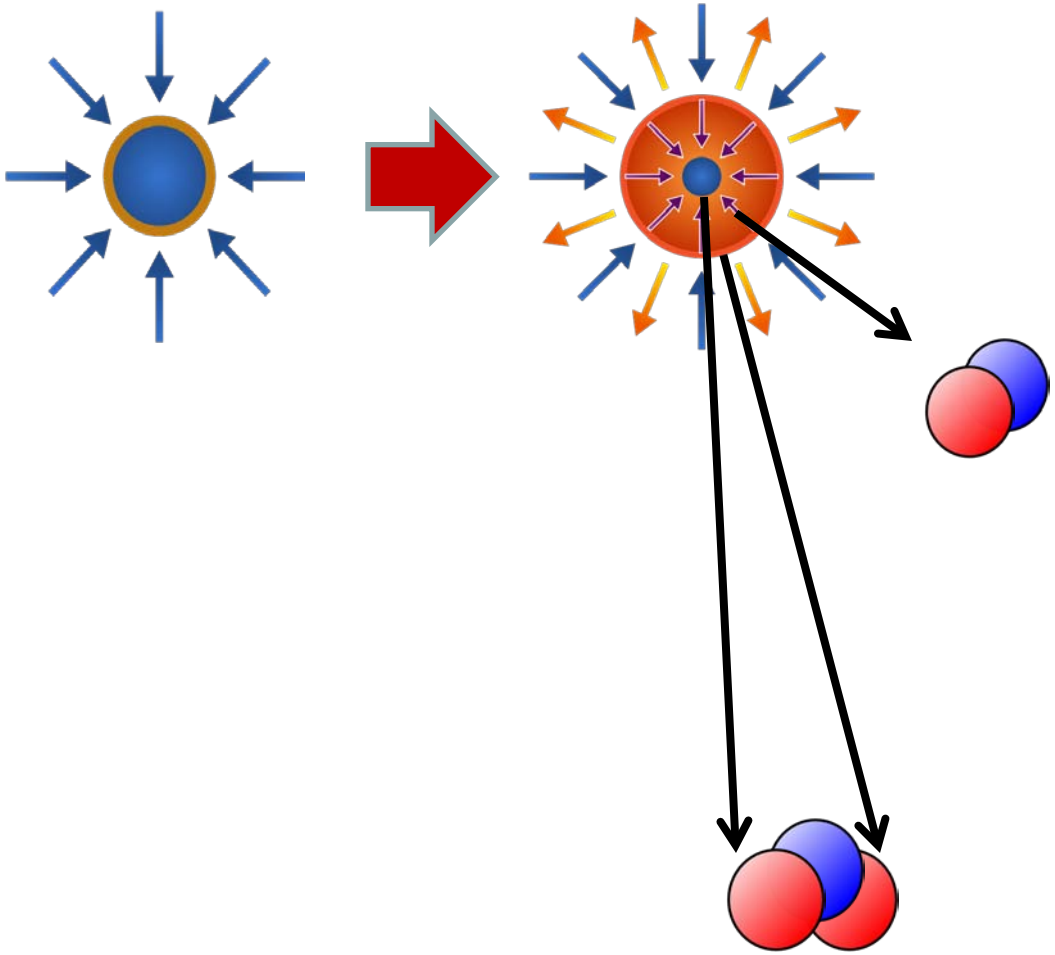
The pathway to ignition

Heat Target **Compression**



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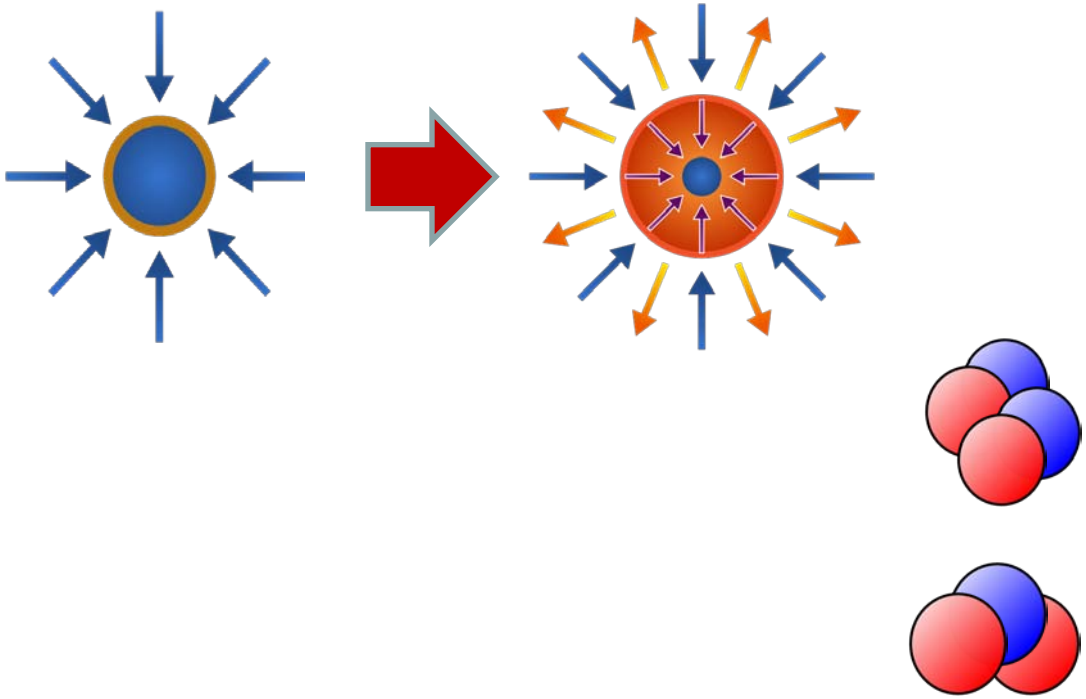
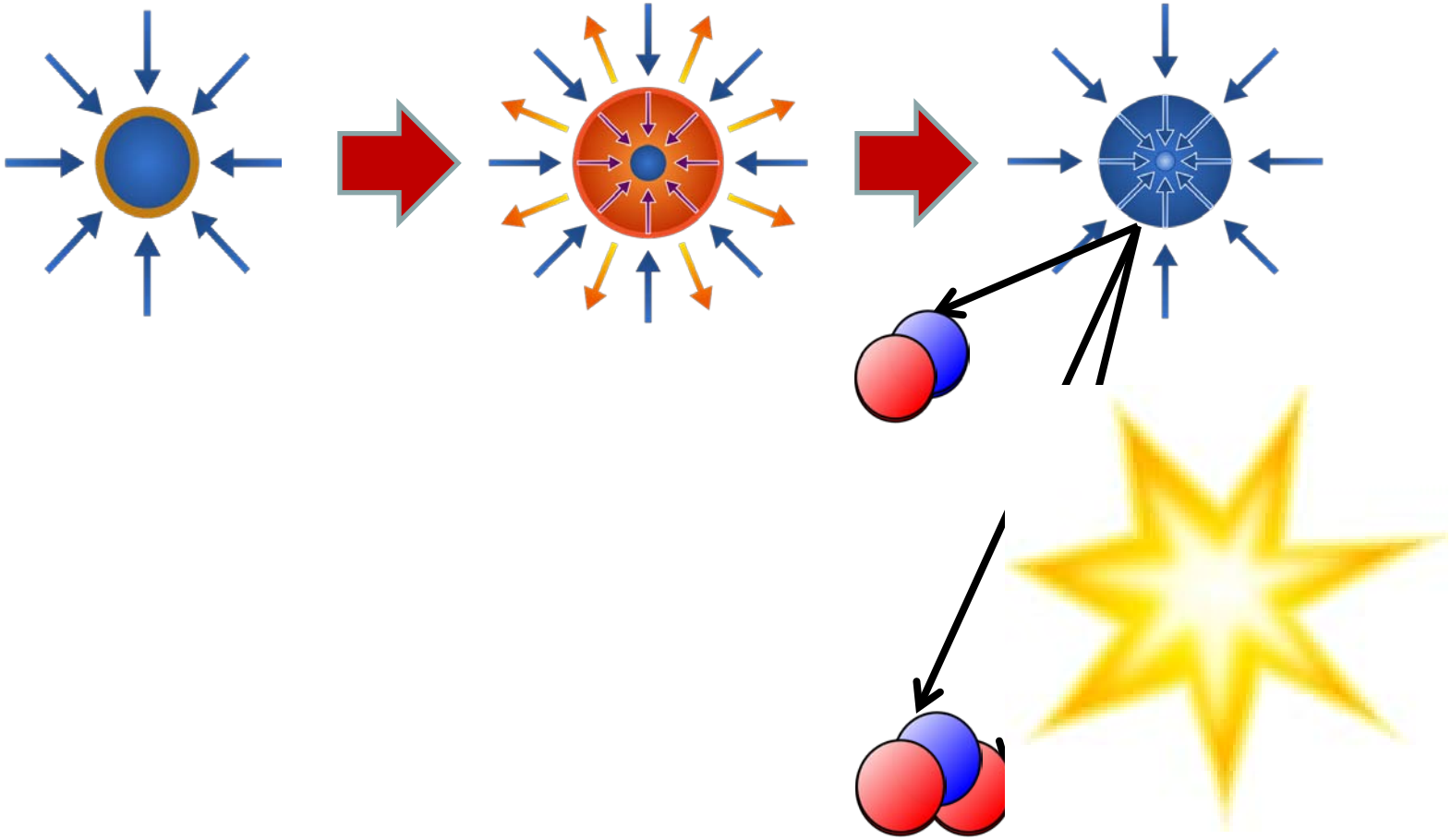
The pathway to ignition

Heat Target **Compression**



The pathway to ignition

Heat Target **Compression** **Implosion**



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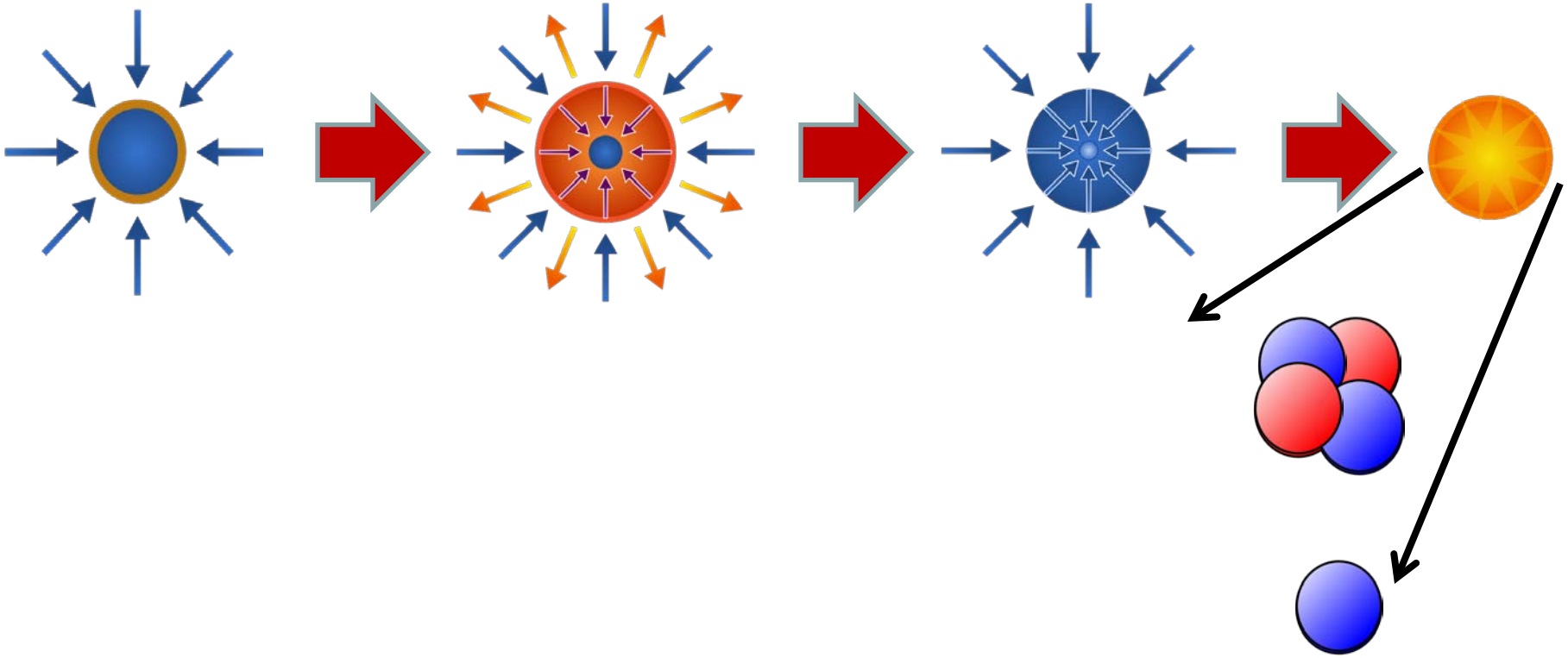
The pathway to ignition

Heat Target **Compression** **Implosion** **Ignition**



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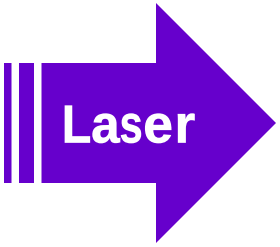
How much power does it take?

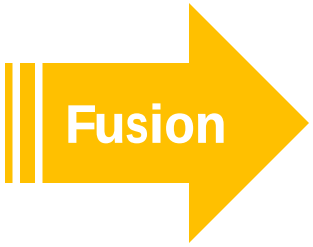
Apply
500 TeraWatts (TW)



For 20 billionths of a second

Ignition

10-100x Input Energy



10 billionths of a second later

500 TW = 5 Million, 100-Watt Light Bulbs!

Wikimedia Commons User: KMJ

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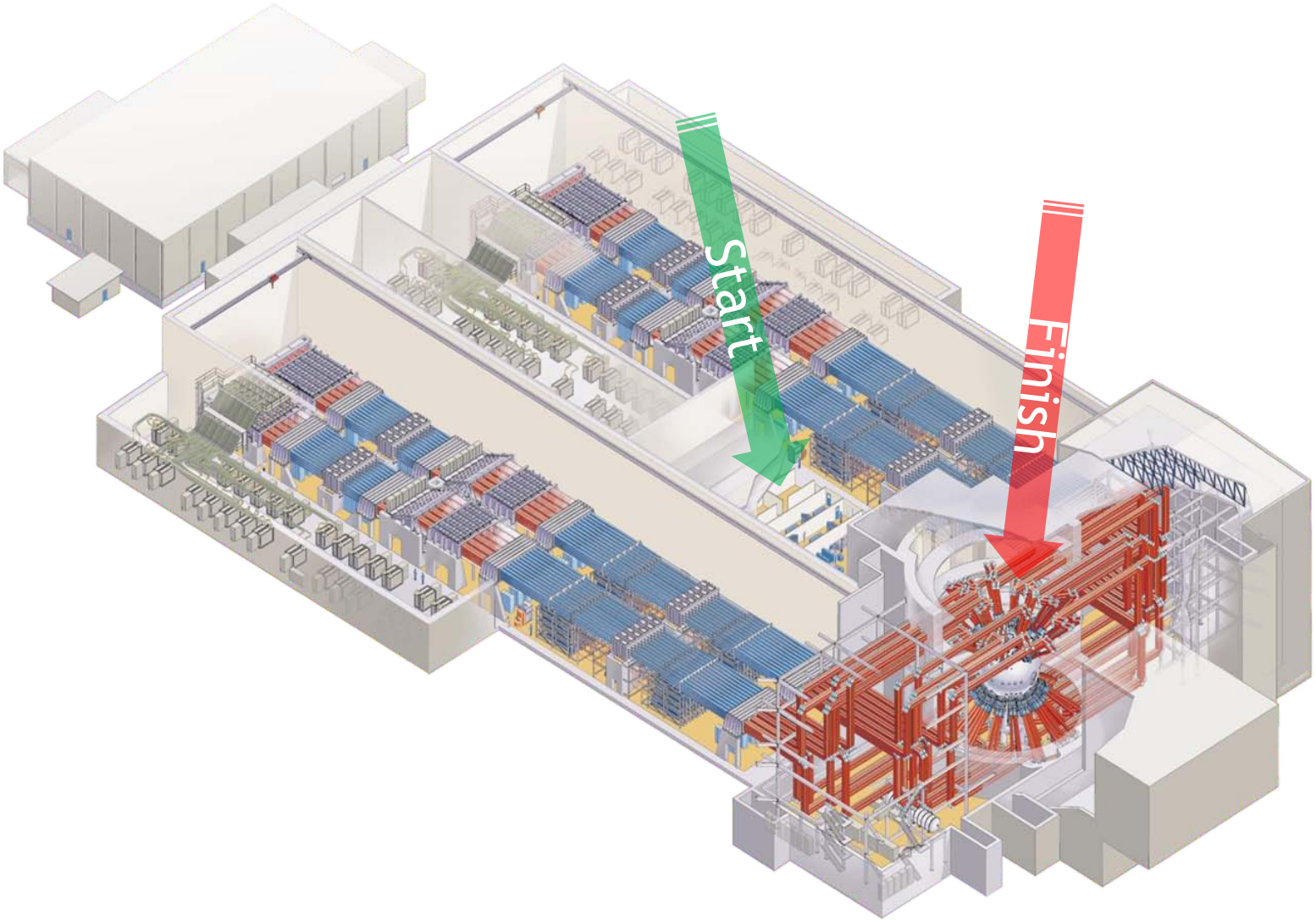
III. Tools of the Trade

The National Ignition Facility (NIF)

World's largest and most energetic laser

Aerial photo of NIF credit: Lawrence Livermore National Laboratory

The inner workings of NIF



NIF layout image credit: Lawrence Livermore National Laboratory

The journey of light in NIF

NIF tour credit: Lawrence Livermore National Laboratory

The current status of NIF

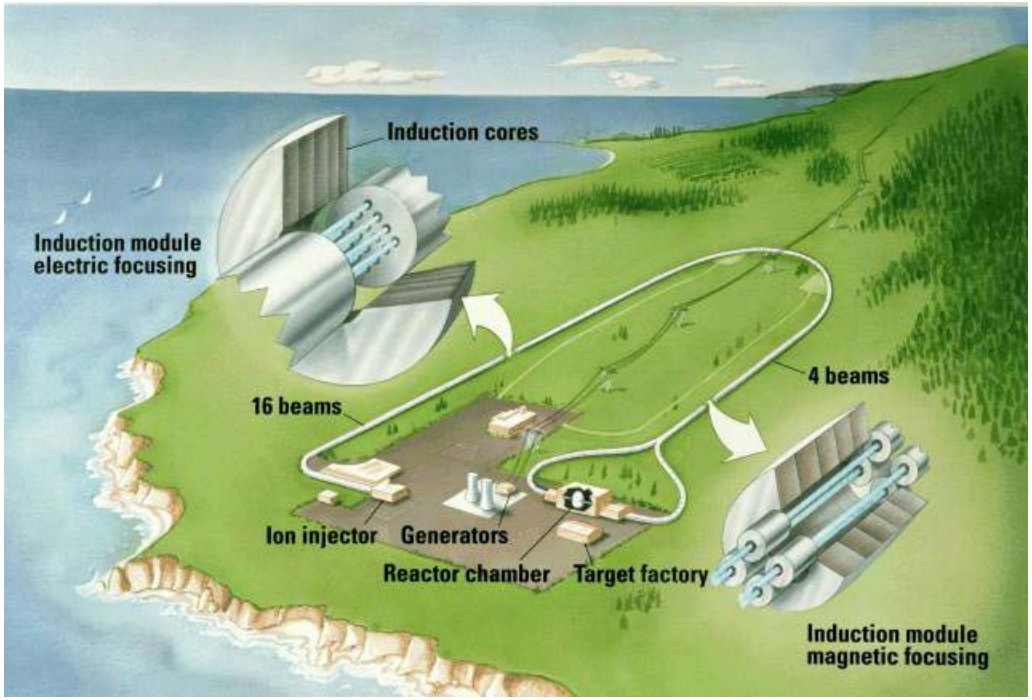
- Construction of NIF was completed in 2009.
- NIF has already set several records as the world's most energetic laser.
- Currently tests and preparation are underway to ready the laser for high-energy operation this year

IV. Toward Clean Energy and Beyond

Proposed Focus Areas of NIF

Astrophysics

Fusion Energy



Hubble Telescope Supernova image credit: NASA, Space Telescope Institute & European Space Agency.
Fusion Power: Lawrence Berkeley National Laboratory.

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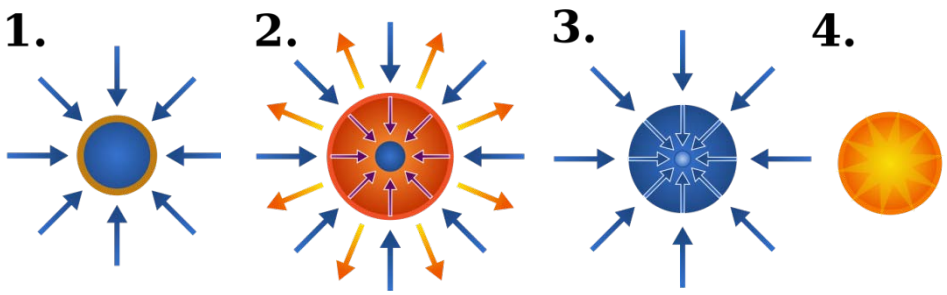
Summary

- Nuclear fusion may enable our clean energy future.
- Nuclear fusion combines lighter atomic nuclei into heavier nuclei and releases energy.
- The current challenge of fusion is ***ignition***.
- NIF, the world's largest and most energetic laser, is designed to achieve ignition.



Wikimedia Commons Users: KayEss (balloons), B. D. Esham (ICF cycle, modified)
NIF aerial photograph image credit: Lawrence Livermore National Laboratory.

Thank you!

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- Harvard Medical School
  - Office of Communications and External Relations
  - Division of Medical Sciences
- The Harvard Graduate School of Arts and Sciences (GSAS)
- The Harvard Biomedical Graduate Students Organization (BGSO)
- The Harvard/MIT COOP
- Restaurant Associates

- SITN is a student organization at Harvard GSAS-