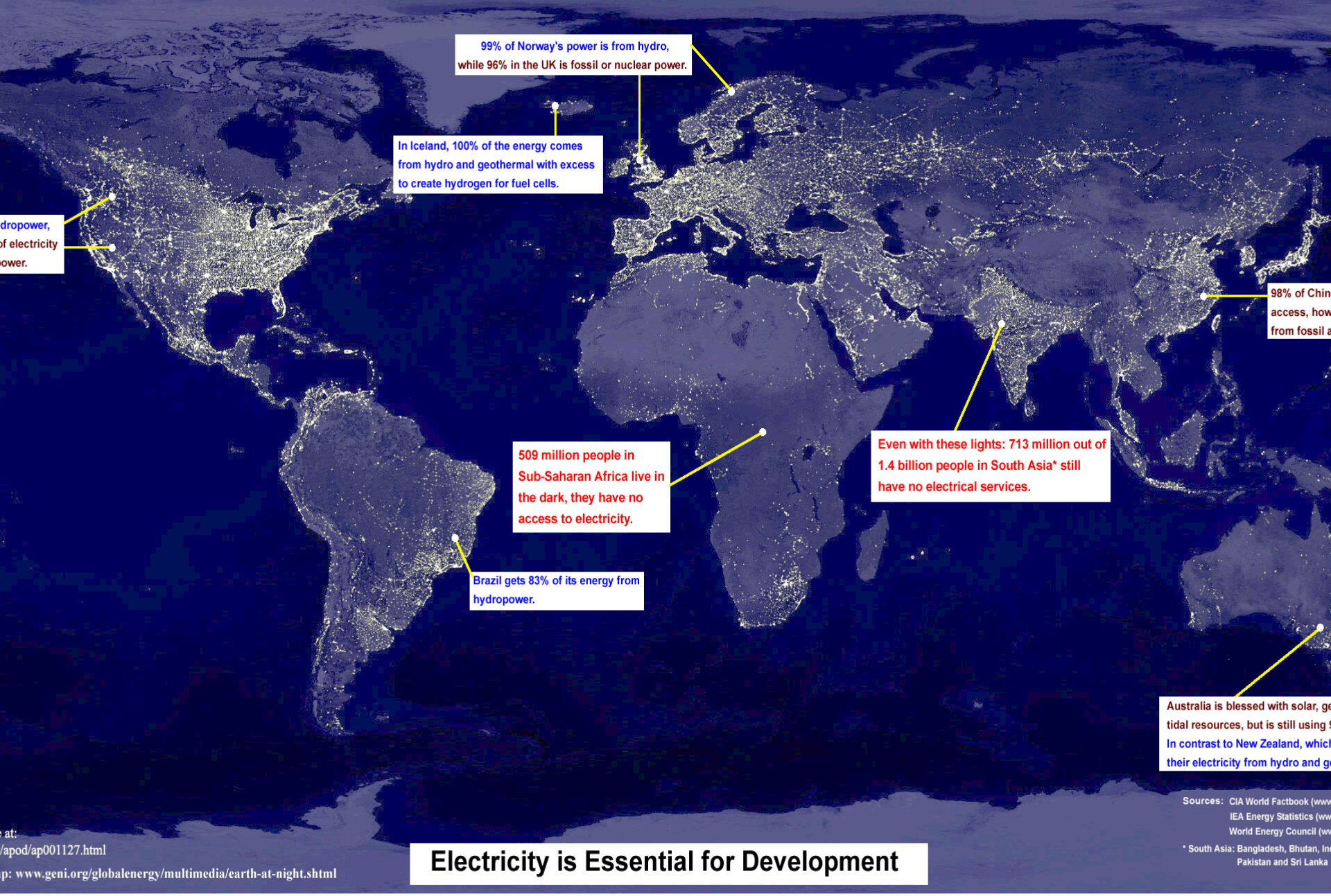
FUSION ENERGY

Dr. Ceri Brenner
Central Laser Facility
STFC

LASER FUSION ENERGY:
A bright approach

Dr. Ceri Brenner
Central Laser Facility
STFC


Electricity generation for the future.....
.....the big challenge

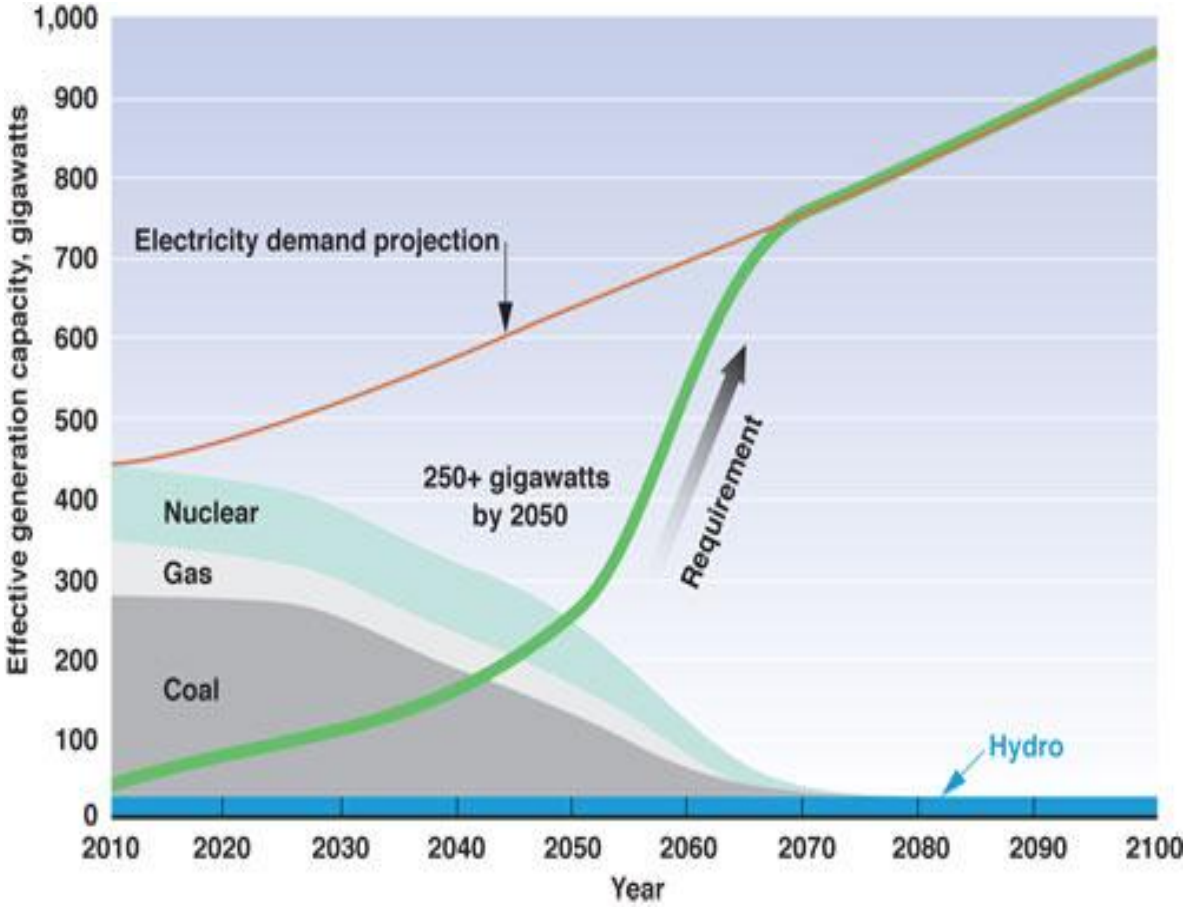


Electricity is Essential for Development

p from NASA shows areas of prosperity -- those people with access to electricity. 1.6 billion, 25% of
he dark -- with no access to running water, refrigeration or lighting. Nearly all the lights in this picture
voltage transmission lines, and 100 nations already exchange power across borders. To meet the UN
ent Goals, a combination of grid-connected and stand-alone renewable electricity development will

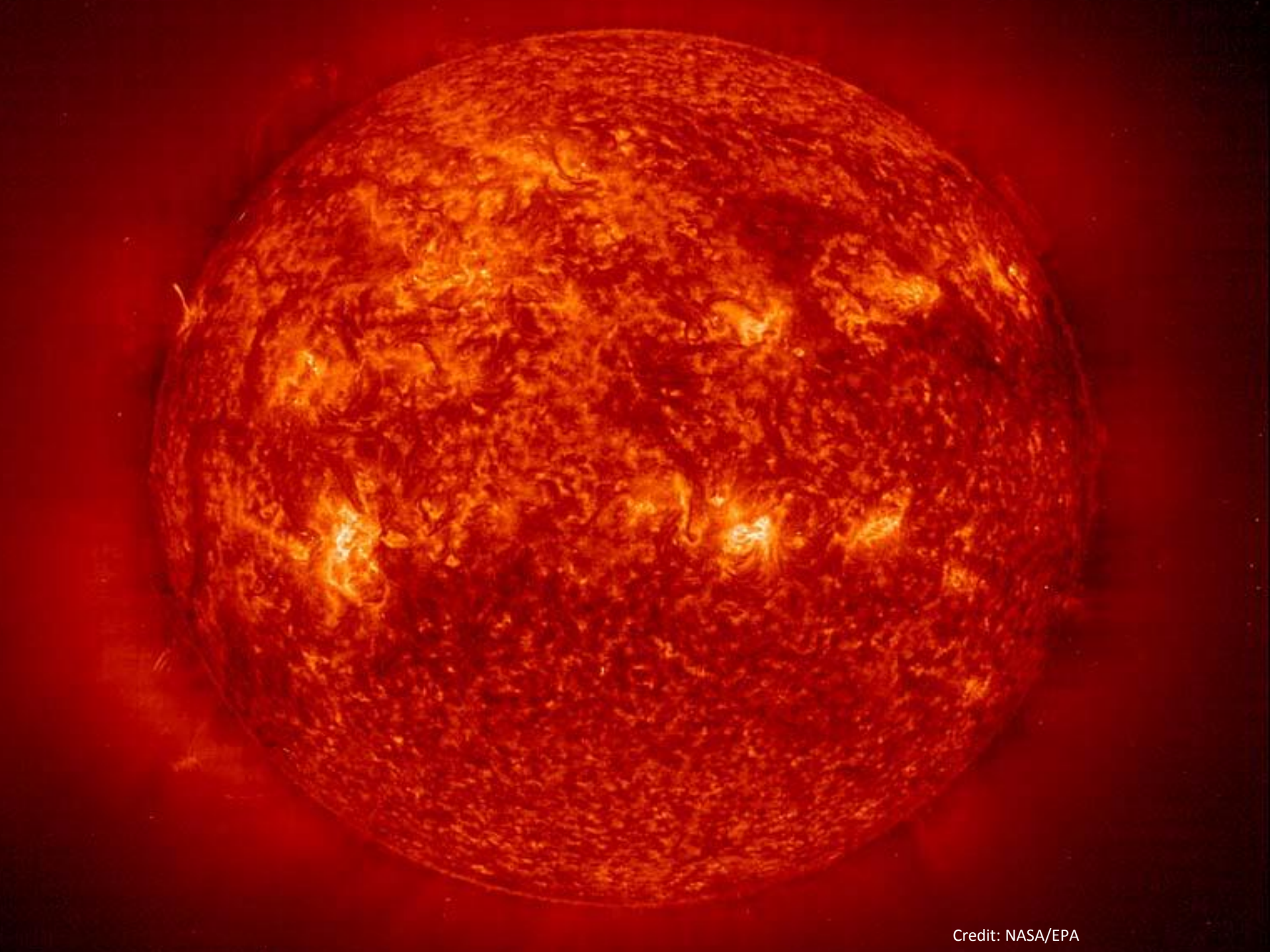
elevate a community out of basic poverty in an environmentally sustainable manner. While mo
polluting fossil and nuclear fuels, abundant renewables -- hydro, geothermal, biomass, wind a
every continent. Linking the renewable electricity resources in Africa and South Asia will provi
ending hunger and poverty.

THE ENERGY DEFICIT



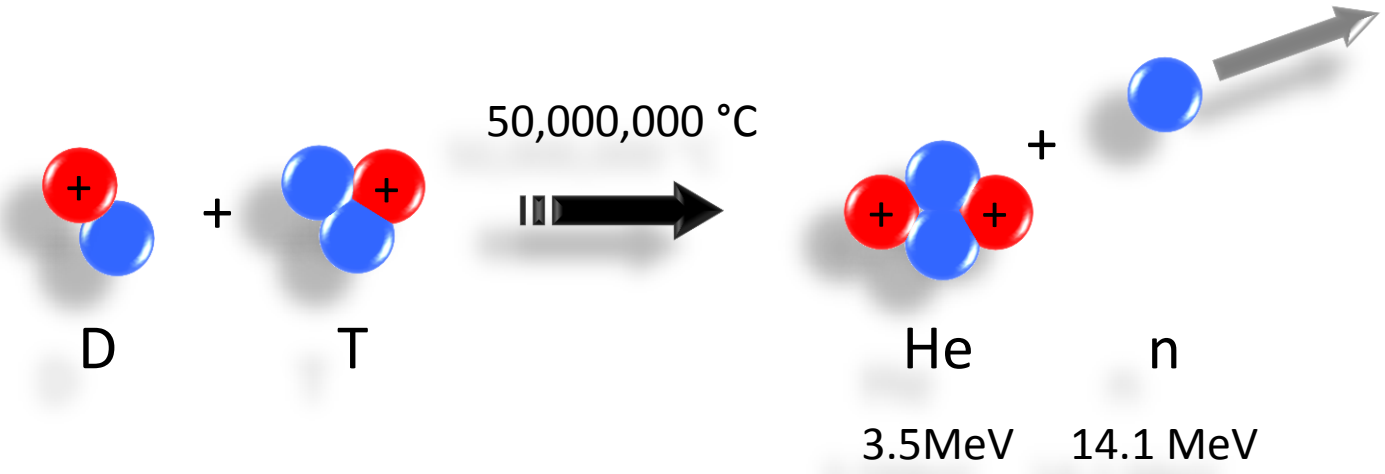
Source: U.S. Energy Information Agency's Annual Energy Outlook, 2009 and LIFE project

Science & Technology Facilities Council



Credit: NASA/EPA

FUSION ON EARTH



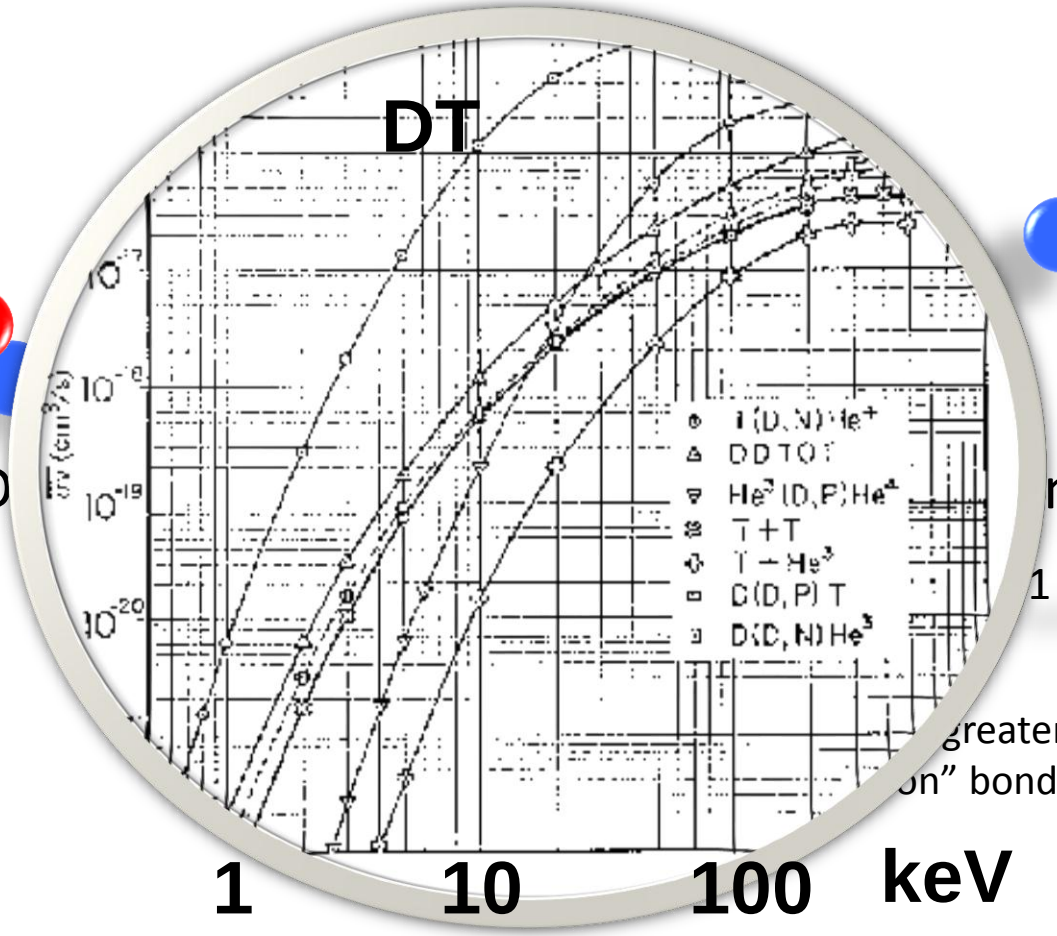
~ a million times greater than chemical "electron" bond energy

converting mass into energy

$$E = mc^2$$

Science & Technology Facilities Council

FUSION ON EARTH



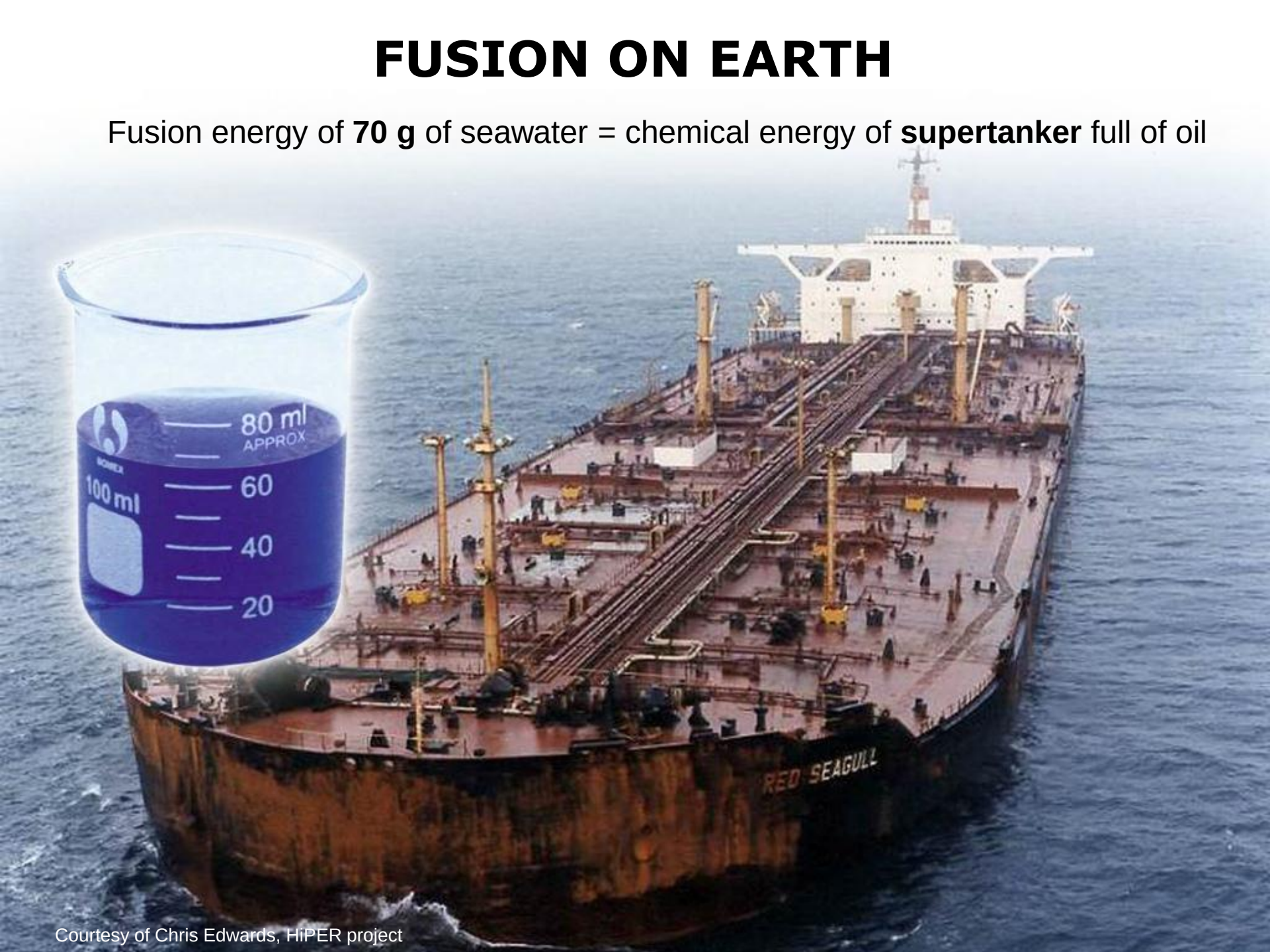
converting mass into energy

$$E = mc^2$$

Science & Technology Facilities Council

FUSION ON EARTH

Fusion energy of **70 g** of seawater = chemical energy of **supertanker** full of oil



Courtesy of Chris Edwards, HiPER project

FUSION ON EARTH

- clean

- abundant source of fuel

- safe

- achievable, affordable

Science & Technology Facilities Council

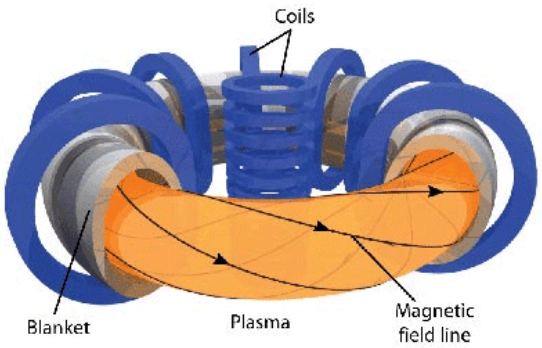
FUSION ON EARTH

IGNITION: more energy out than goes in

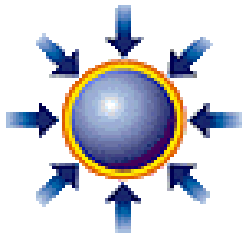
IGNITION: significant fraction of the fuel burnt

Lawson criterion: "triple product"

$$n_e T \tau \geq 10^{21} \text{ keV s/m}^3$$



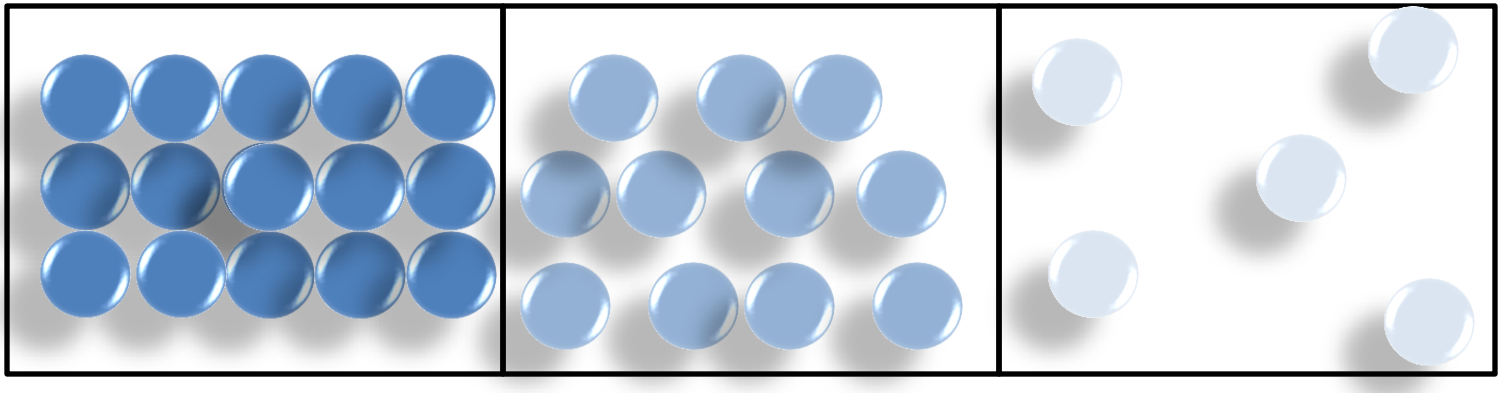
Magnetic confinement, MCF

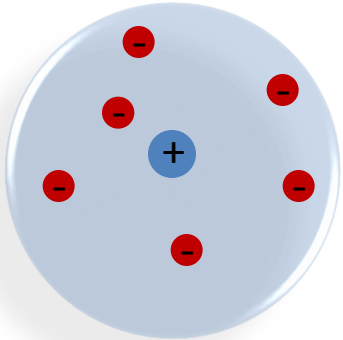


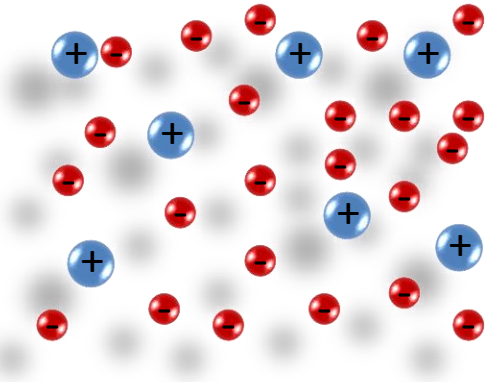
Inertial confinement, ICF

Science & Technology Facilities Council

P L A S M A: the 4th state of matter

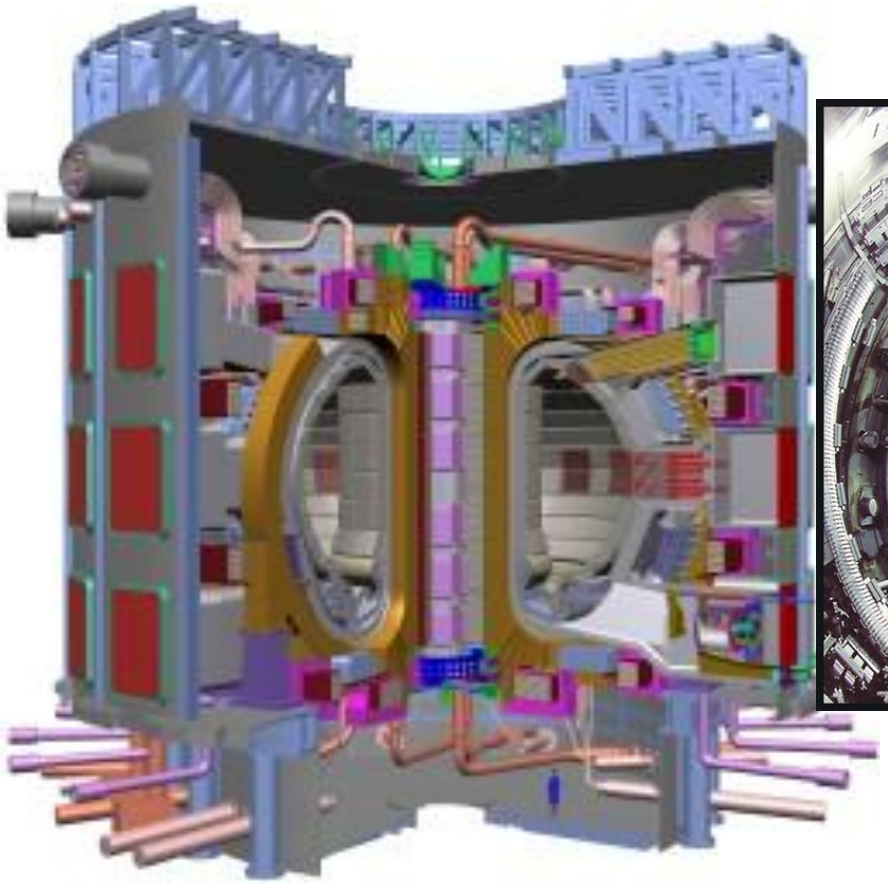




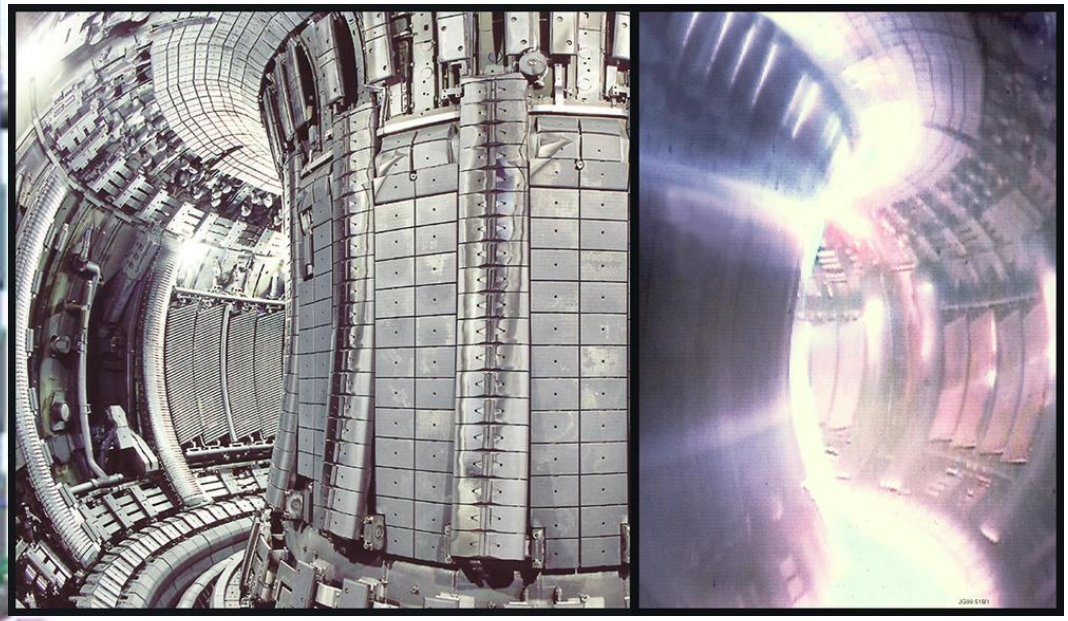


Science & Technology Facilities Council

FUSION ON EARTH



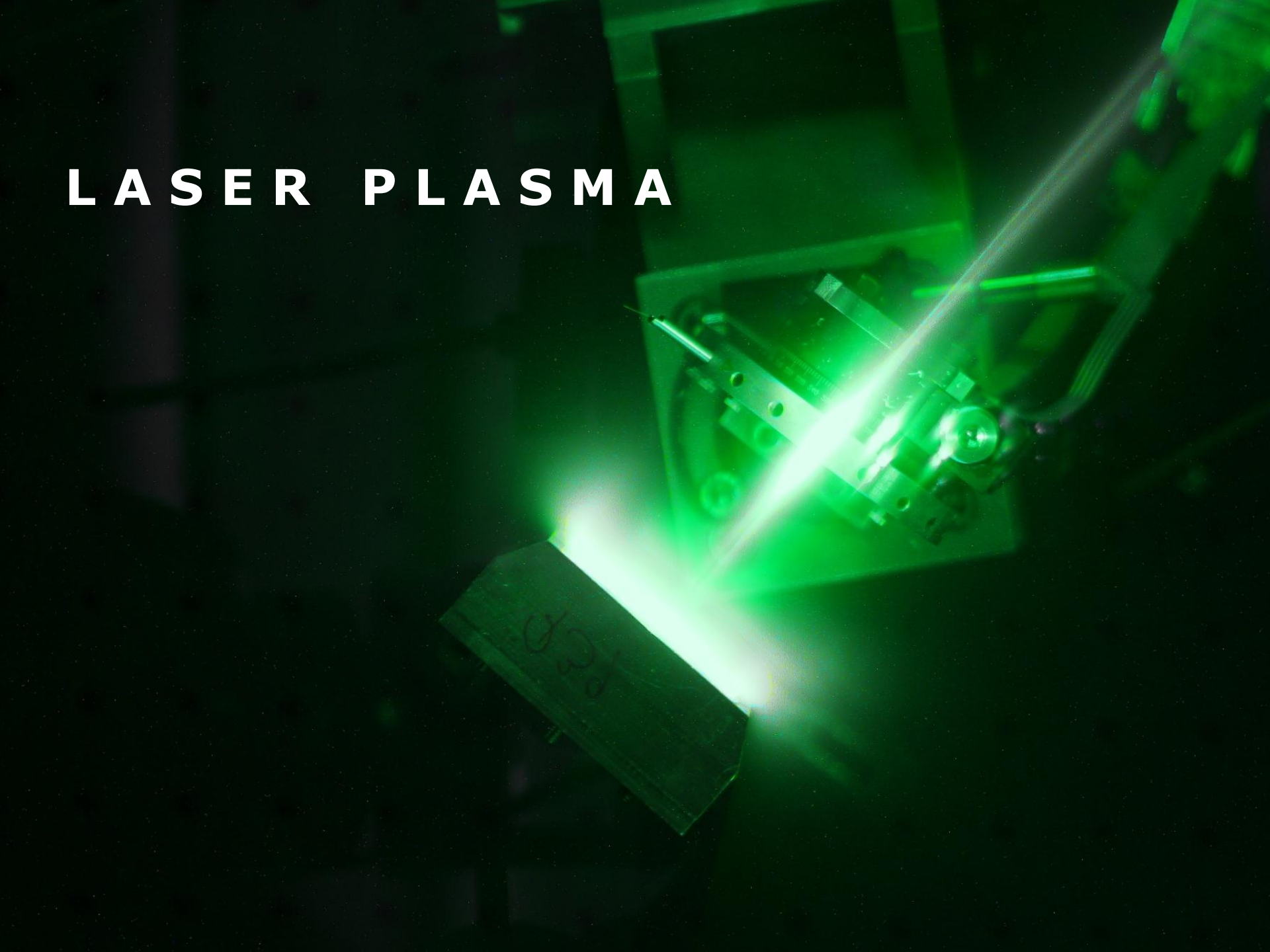
ITER project tokamak



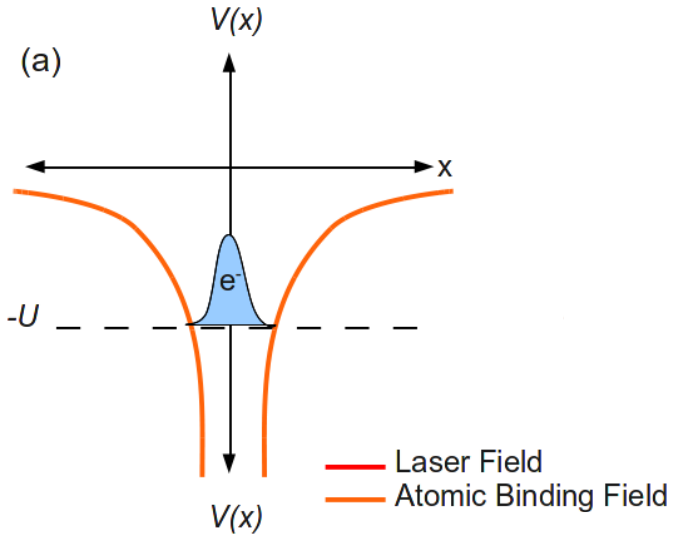
JET tokamak, Culham, Oxfordshire

Science & Technology Facilities Council

LASER PLASMA

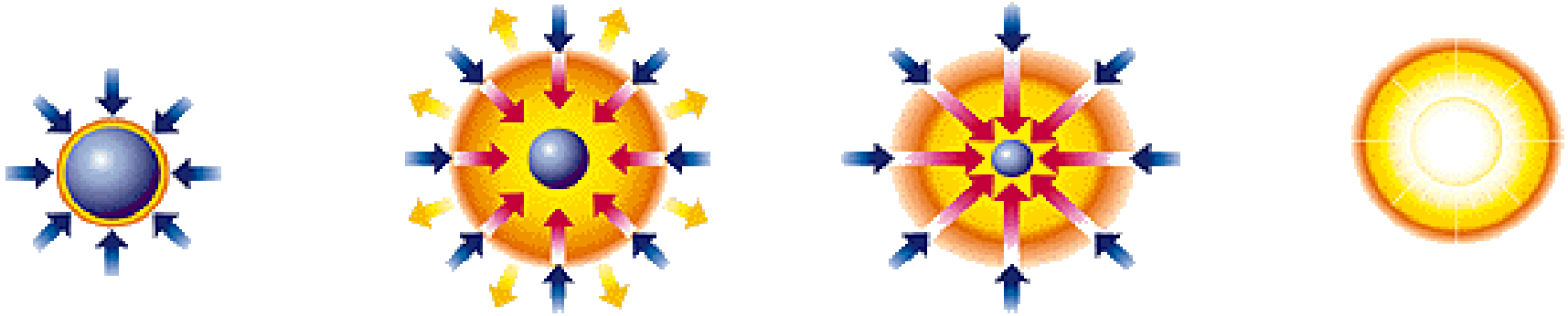


L A S E R P L A S M A (the best kind)



Science & Technology Facilities Council

FUSION ON EARTH



20 times density of lead

50’000’000 ° C

Science & Technology Facilities Council

ICF ρR condition

Working with a hotspot of ~ 10 keV

Lawson criterion dictates $n\,\tau > 10^{20}$ s / m^3

Shock wave moving at local sound speed ~ 10^6 m/s

$$\frac{\rho R}{m_i c_s} > 10^{20}$$

$$\boldsymbol{\rho R > 0.3\ g/cm^2}$$

Science & Technology Facilities Council

“ideal” level of compression is the maximum practically achievable (~5000 x)

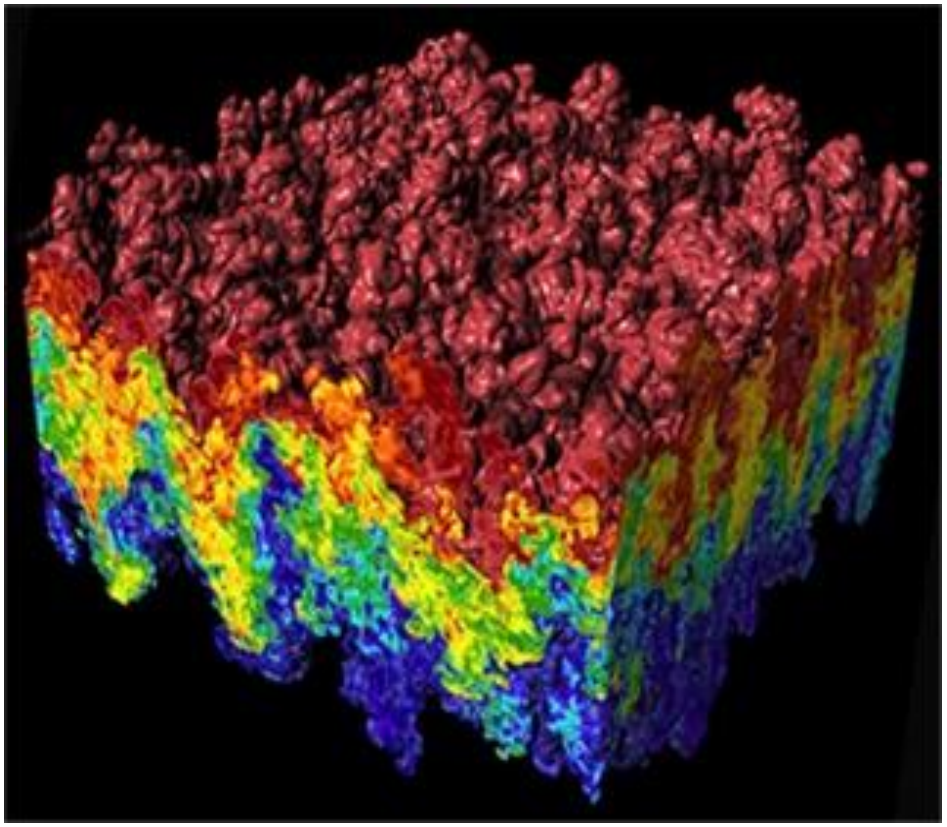
- Denser fuel requires less energy to ignite, since, in spherical geometry, the mass of fuel satisfying ρR ~0.3g/cm^2 goes with ρ^{-2}

- limited by the achievable implosion velocity, which is in turn limited by the allowable laser intensity/ hohlraum temperature, as well as considerations of hydrodynamic stability…

Science & Technology Facilities Council

Plasma instabilities

Rayleigh-Taylor fluid instabilities



dense fluids being pushed on, or supported, by less dense fluids are unstable

causes capsule to become highly distorted, interfering with the stagnation process and preventing the desired conditions for fusion being reached as well as leading to mixing of fuel with ablator material

Heating

PdV work done on fuel during implosion

Alpha particle heating

Cooling

Electron conduction

Radiative losses

PdV work done by the fuel during explosion

Science & Technology Facilities Council

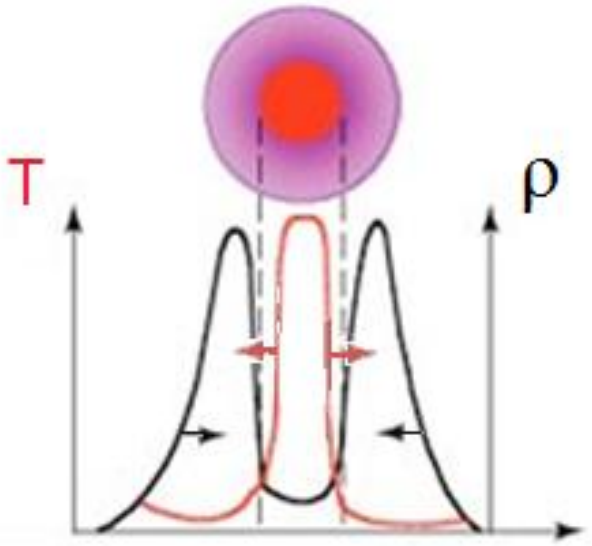
Bang time. Feel the burn

Hot fuel is transparent to own alpha emission

Cold fuel is opaque to alphas radiating from burning regions

Burn propagates as cold fuel is heated to transparency, resulting in power output concentrating on heating the next layer

Burn wave eventually runs into inward propagating rarefaction wave coming from surface of dense fuel



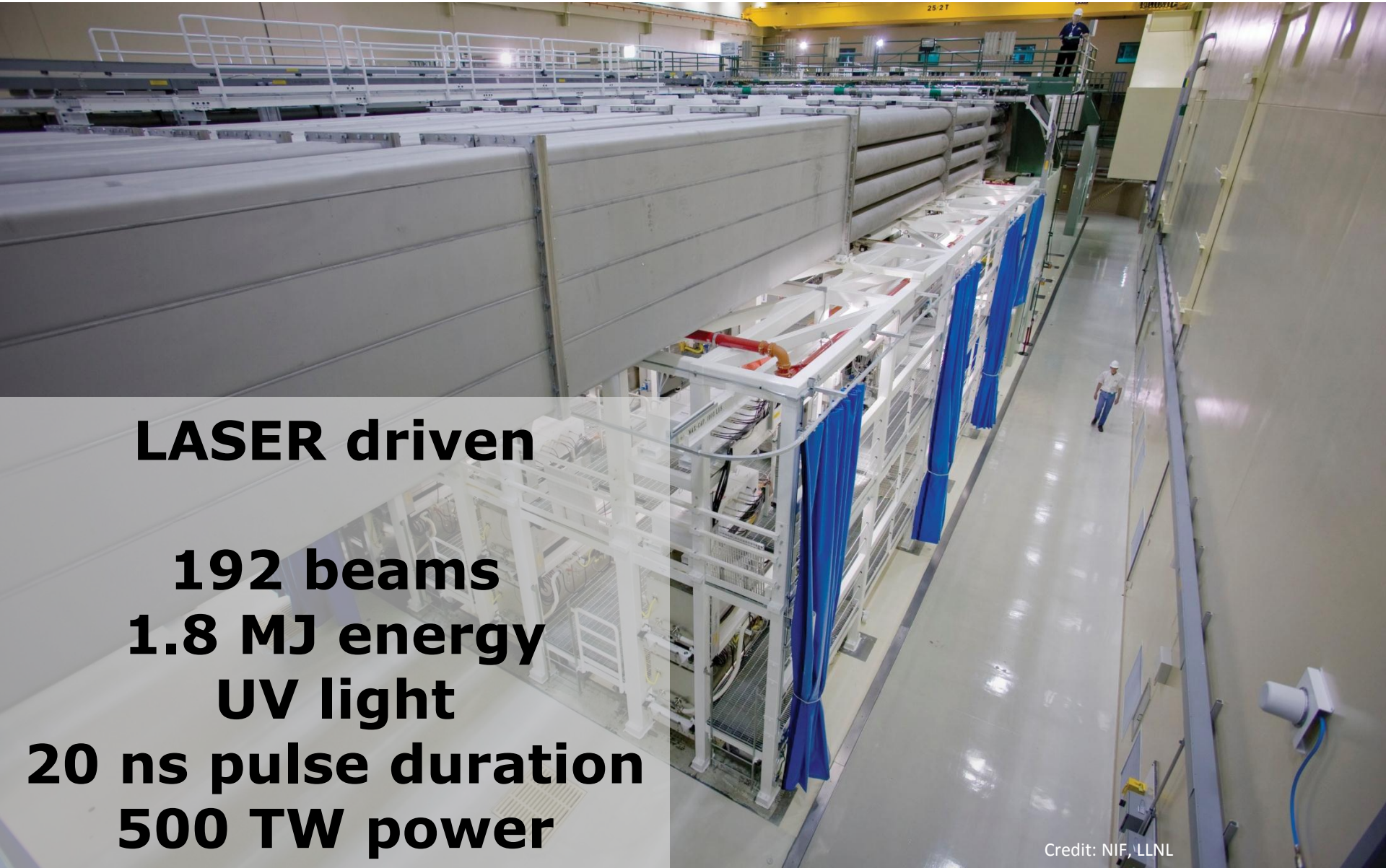
Science & Technology Facilities Council

FUSION ON EARTH

National Ignition Facility (NIF)

Science & Technology Facilities Council

FUSION ON EARTH

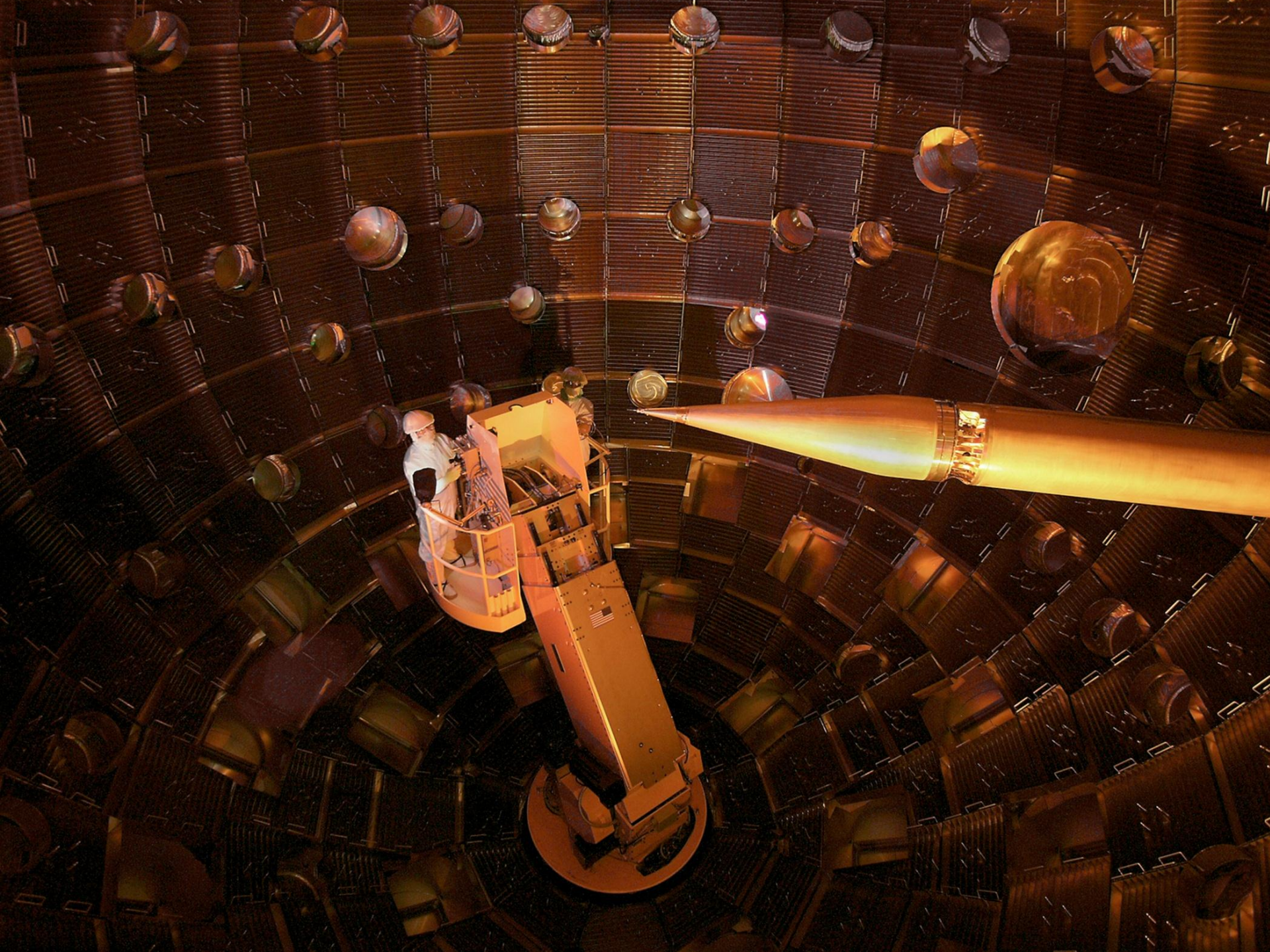


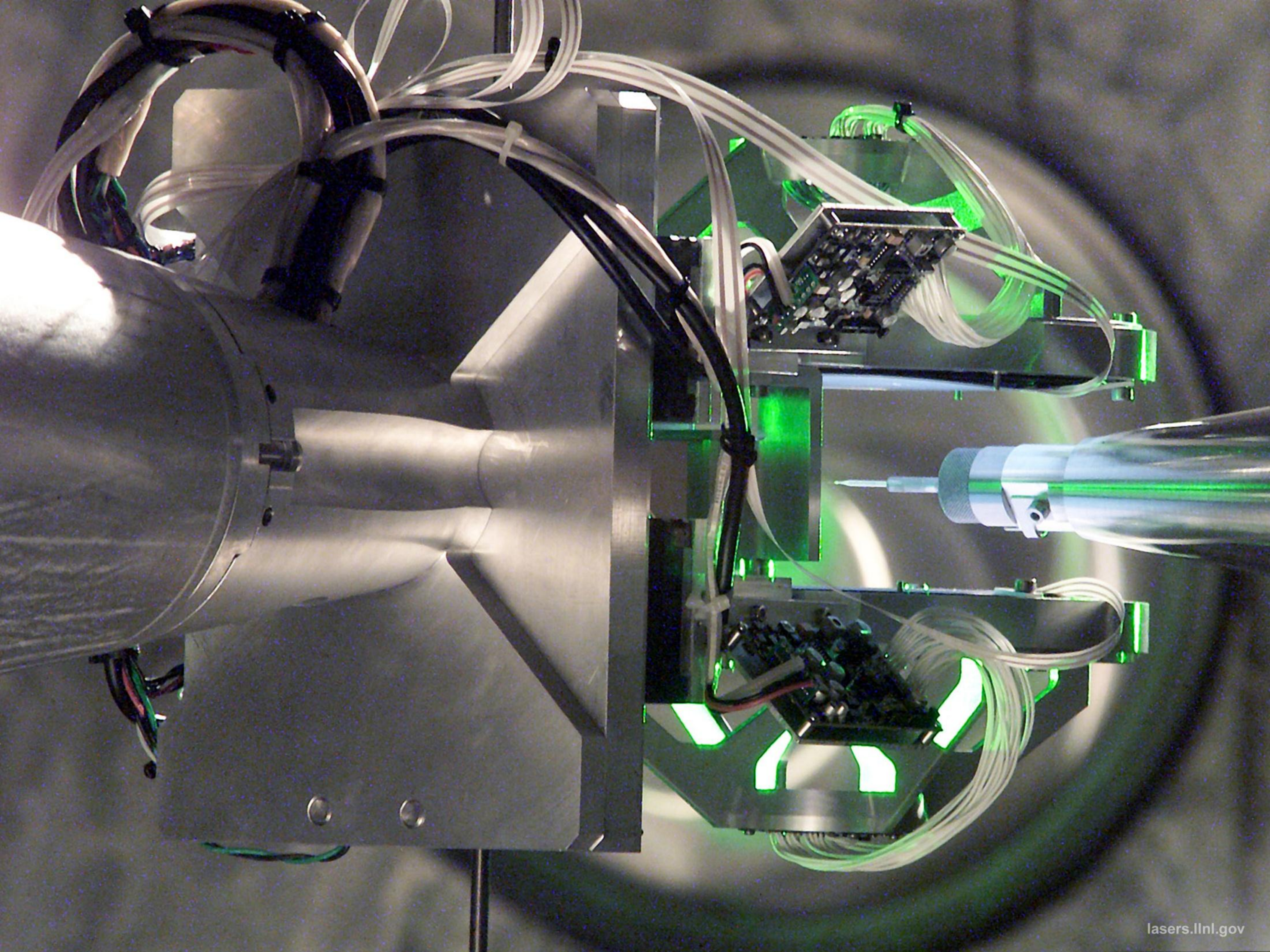
LASER driven

192 beams
1.8 MJ energy
UV light
20 ns pulse duration
500 TW power

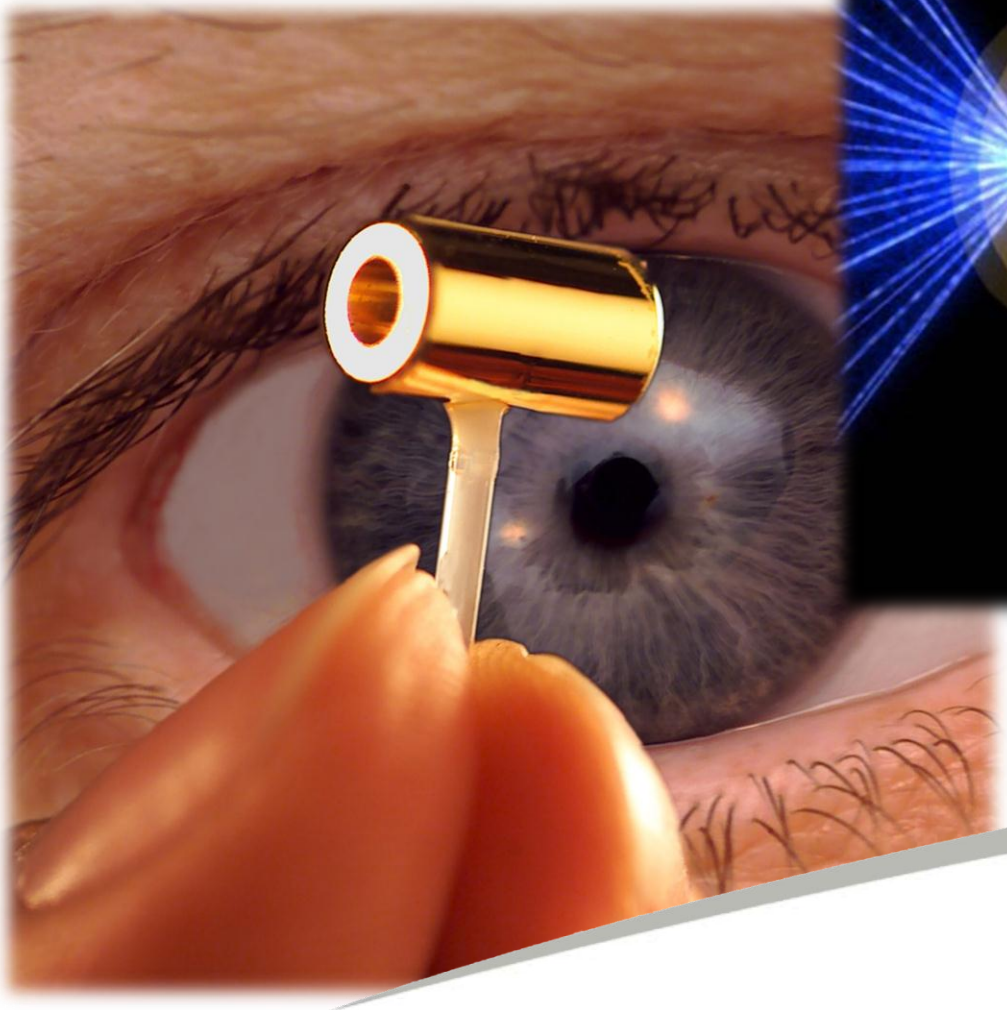
Credit: NIF, LLNL

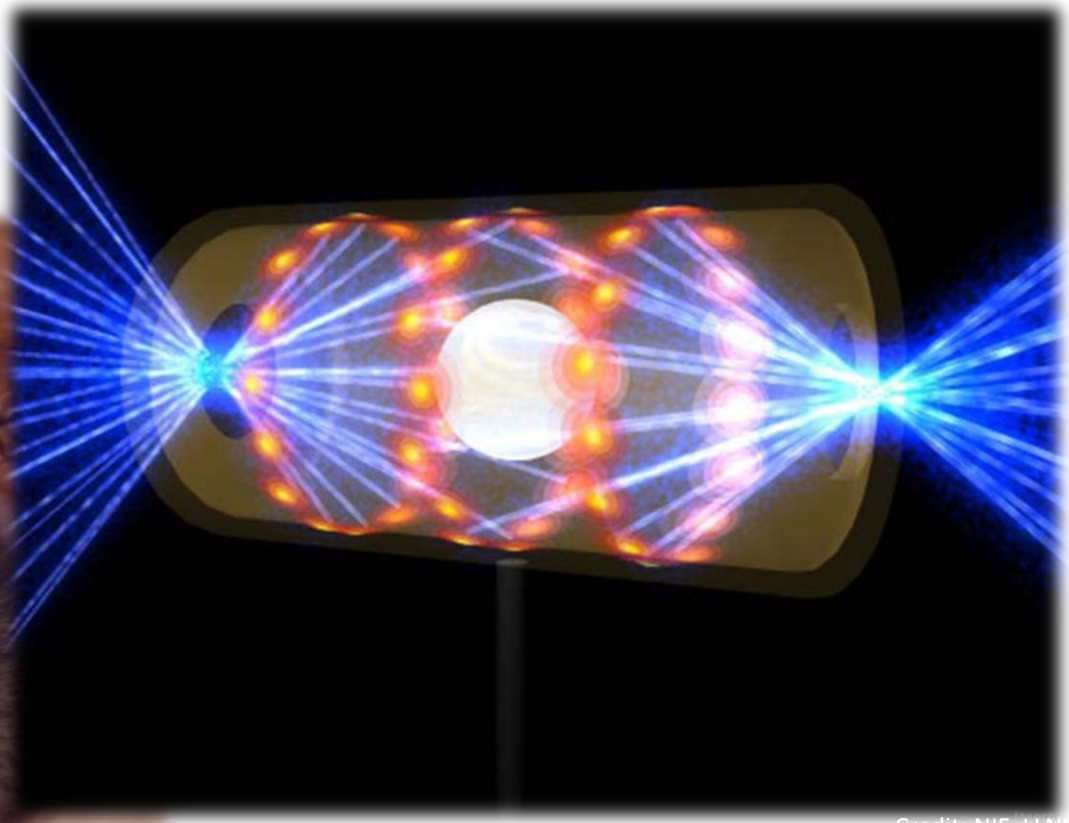

LBS-MPA-AV 1-18
LBS-MPA-AV 2-18
lasers.llnl.gov




lasers.llnl.gov

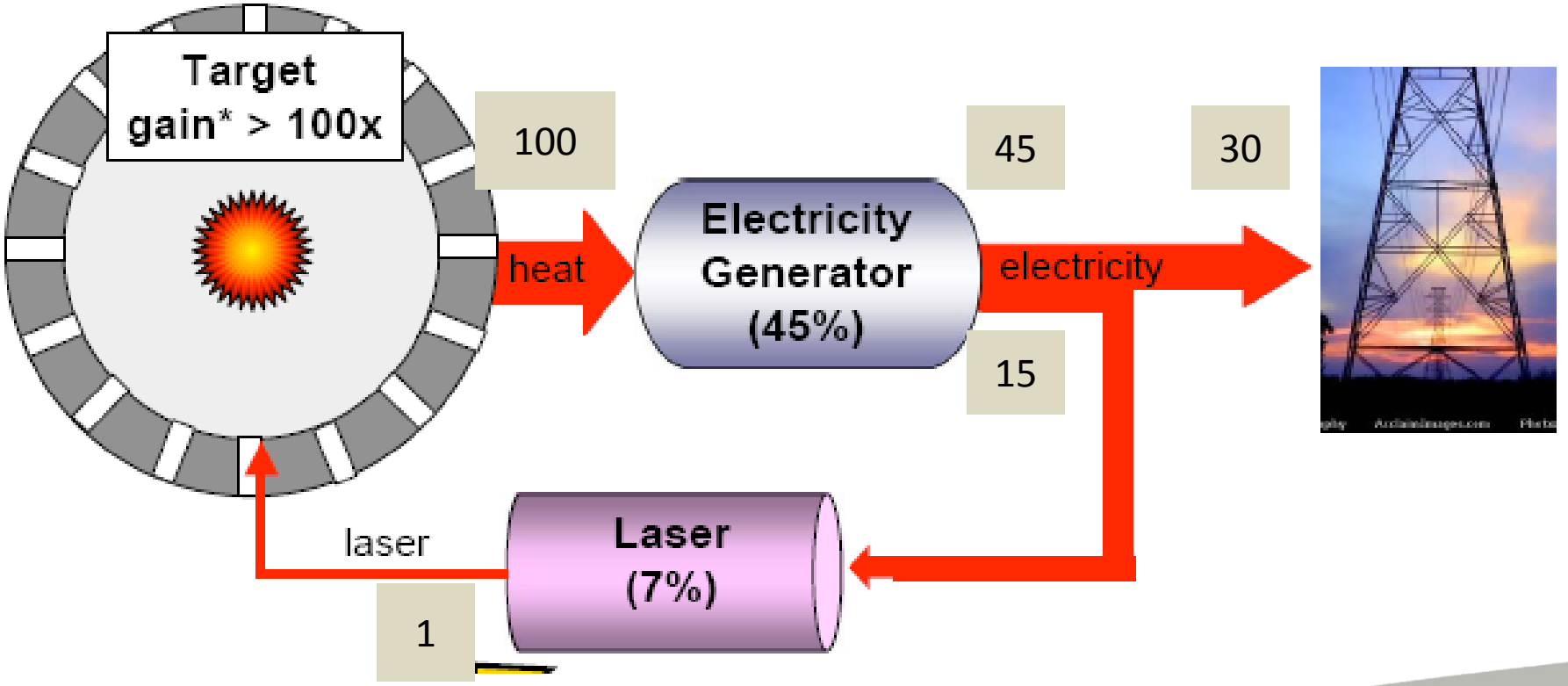
FUSION ON EARTH





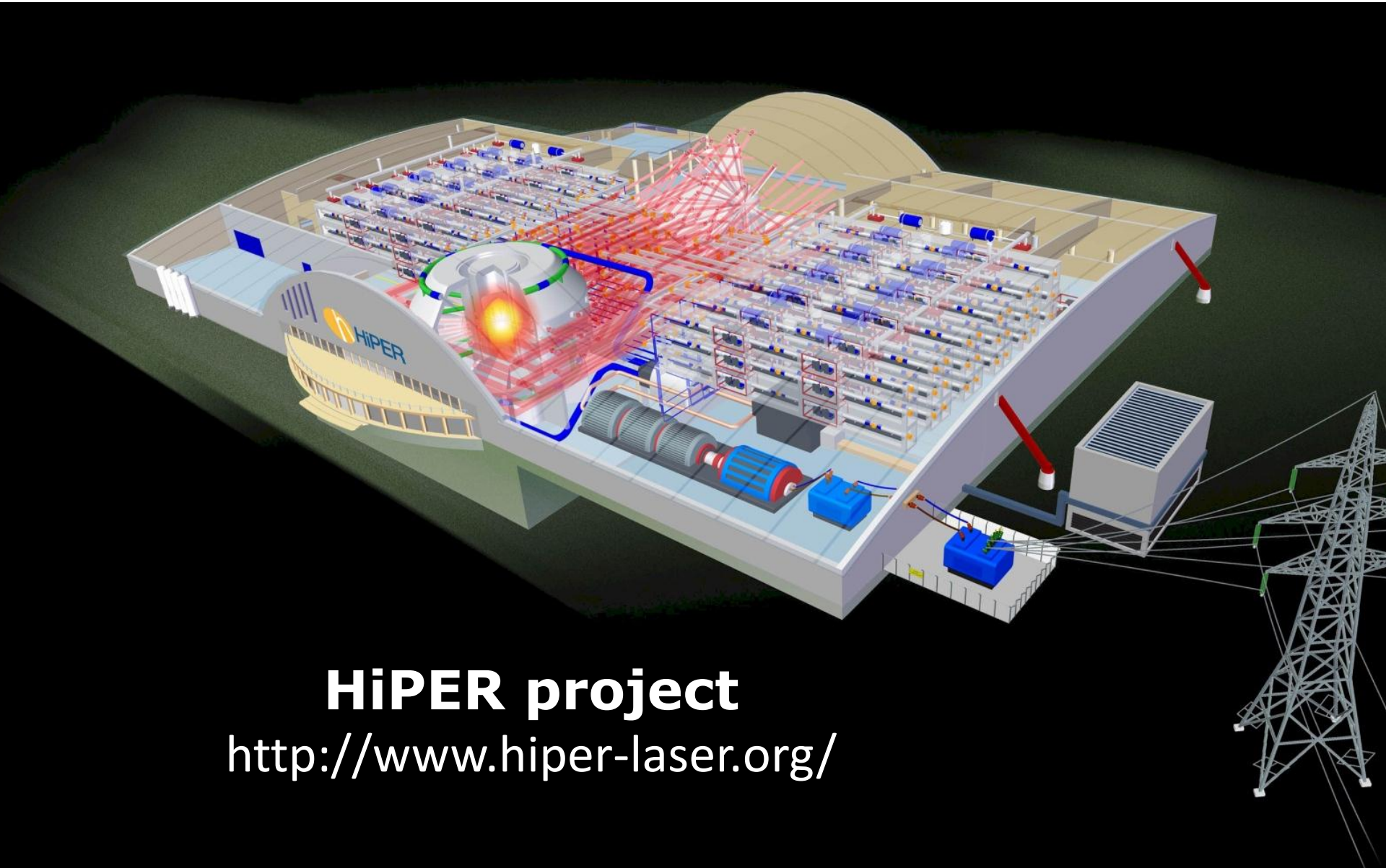
Science & Technology Facilities Council

FUSION POWER ON EARTH



Science & Technology Facilities Council

FUSION POWER ON EARTH



HiPER project

http://www.hiper-laser.org/

INTERESTED?

MSc Fusion, University of York

http://www.york.ac.uk/physics/postgraduate/fusion-msc/

University | A to Z | Departments

THE ONE HUNDRED UNDER FIFTY
NUMBER ONE IN THE UK
EIGHTH IN THE WORLD

- Physics home
- About the Department
- Undergraduate study
- Postgraduate study
  - Degrees on offer
  - PhD in Physics
  - MSc by Research in Physics
  - PhD/MSc research projects
  - MSc in Fusion Energy
    - Course details
    - MSc Projects
  - Fusion Doctoral Training Network
  - Graduate Diploma in Physics
  - Modules for Research students
  - Graduate Professional Development
  - S.I.E.S.T.A. Graduate Seminars

Fusion Energy MSc (taught)

The Course

Fusion offers the prospect of an effectively limitless supply of energy which is relatively clean and produces no greenhouse gases. Fusion research is focused around two main concepts: magnetic confinement fusion (MCF) and inertial confinement fusion (ICF). Both will be covered in this MSc course. The field is entering an exciting new era with the construction of the ITER tokamak in the South of France. There are also large ICF projects on the horizon, such as NIF and HiPER.

The University of York now provides a taught MSc in Fusion Energy, in response to an international need to train physicists for this recent growth in fusion energy research activity. This Master's course provides a firm foundation to fusion physics and give introductions to some of the more advanced topics. It is an ideal course to prepare students for a PhD in fusion energy; it will also equip students who decide not to pursue fusion further with a range of important generic skills applicable in many sectors of employment.

This Fusion Energy MSc includes lectures, laboratory classes and a major research project which will be carried out over the summer months

Student Destinations

Many of our students are offered PhD positions following the MSc - in both Fusion Energy and other subject areas. Students from the first two MSc cohorts have gone on to PhD study at Oxford, Imperial, Liverpool and York. Other destinations have included teaching and positions in industry.

Several students from the 2011/12 cohort have already secured PhD positions, and will go on to study Fusion Energy at York, Complexity Science at Warwick, and Applied and Computational Mathematics at Edinburgh.

"I have really enjoyed the MSc - it is a challenging, but very

Science & Technology Facilities Council