IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Nuclear Energy research and applications

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Outline

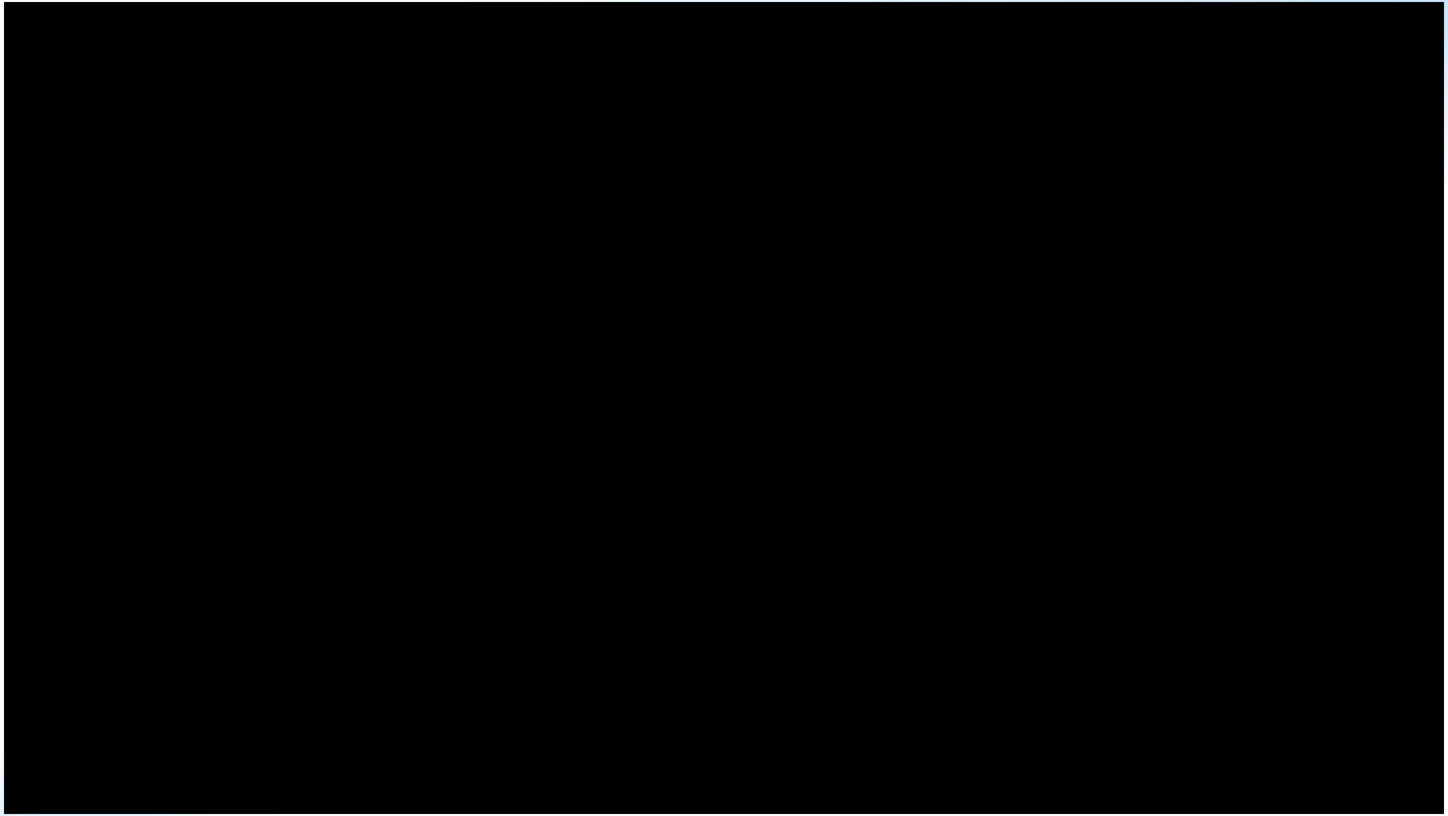
- IAEA – atoms for peace and development
- Division of Physical & Chemical Sciences (NAPC)
- Energy and the African Continent
- R&D related to Nuclear Energy
  - Radiation and nuclear physics
  - The Fuel Cycle – Waste disposal
  - Fusion research and development
  - Nuclear databases

Presentation Objectives

After successful completion of this lecture, students should be able to:

- Understand the mission of the IAEA and how the Division for Physical and Chemical Sciences fits in
- Recall the added value of nuclear energy for Africa
- Recall basic information on fusion energy generation
- Know about the principles of radiation and nuclear physics

International Atomic Energy Agency



Atoms for Peace and Development

IAEA

"The Agency is a formidable institution that deals with issues of war and peace, of human health, of energy, food and water – fundamental concerns of all human beings."

Rafael Mariano Grossi, Director General, IAEA

IAEA at A Glance

1957
IAEA Statute

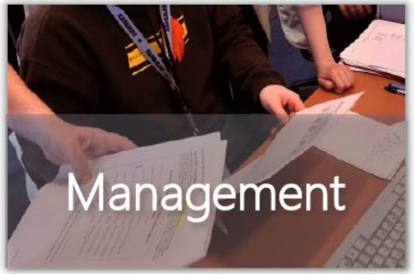
178
Member States
(as of Oct 2023)

2,500+staff
from
over 100
countries

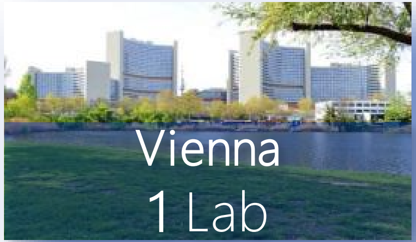
- HQ in Vienna
- Laboratories in Seibersdorf, Monaco and Vienna.
- Regional offices in Toronto and Tokyo.
- Liaison offices in New York and Geneva

Organization

- Director General
- Director General's Office
- Secretariat of the Policy-Making Organs
- Offices of Legal Affairs; Public Information and Communication; and Internal Oversight Services, and
- 6 Departments:



12 unique laboratories



Water Resources

Food & Agriculture

Human Health

Nuclear Science

Environment

Environment (Marine)

UN 2030 Agenda - Sustainable Development Goals

Nuclear science and technology for development in energy, human health, food&agriculture, water management and environmental protection.

IAEA response to global challenges

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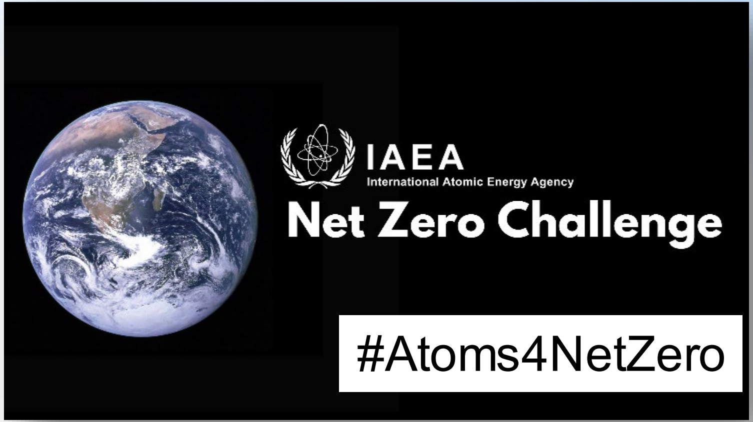
Rays of Hope
Cancer care for all



IAEA - Nuclear Sciences and Applications

Programmes

#atoms4life

IAEA

#atoms4climate

Using nuclear technologies to achieve UN Sustainable Development Goals

- Zero Hunger
- Good Health and Well-being
- Clean water
- Clean energy
- Foster Innovation
- Climate Action
- Life below water and on land
- Partnerships for goals

FAO/IAEA Food & Agriculture

Human Health

Physical and Chemical Sciences

Environmental Laboratories

Division of Physical & Chemical Sciences (NAPC)

Nuclear Data, Nuclear Science, Physics, Radiation and Isotope Sciences & Applications, Water resource management

Nuclear Data
- Data Development
- Data Services
- Atomic & Molecular Data

Physics
- Accelerator Applications
- Nuclear Instrumentation
- Nuclear Fusion
- Research reactor applications

NE

Radiochemistry & Radiation Technology
- Medical Radioisotope production, Radiopharmaceuticals
- Radiotracers, NCS & NDT in industry
- Radiation technology applications
- Terrestrial Environment

Isotope Hydrology
- Isotopic methods for groundwater assessment
- Water resource management
- Scenario modelling

NA

Division of Physical & Chemical Sciences (NAPC)

IAEA

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Melissa Denecke

Head Nuclear Data Section

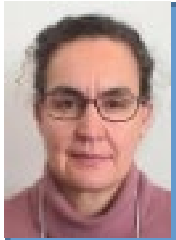
Arjan Koning

Head Physics Section

Danas Ridikas

Head Radiochemistry & Radiation Technologies

Celina Horak



Head Isotope Hydrology Section

Jodie Miller

Lab Head NSIL

Kalliopi Kanaki

Lab Head TERC

Jonathon Burnett

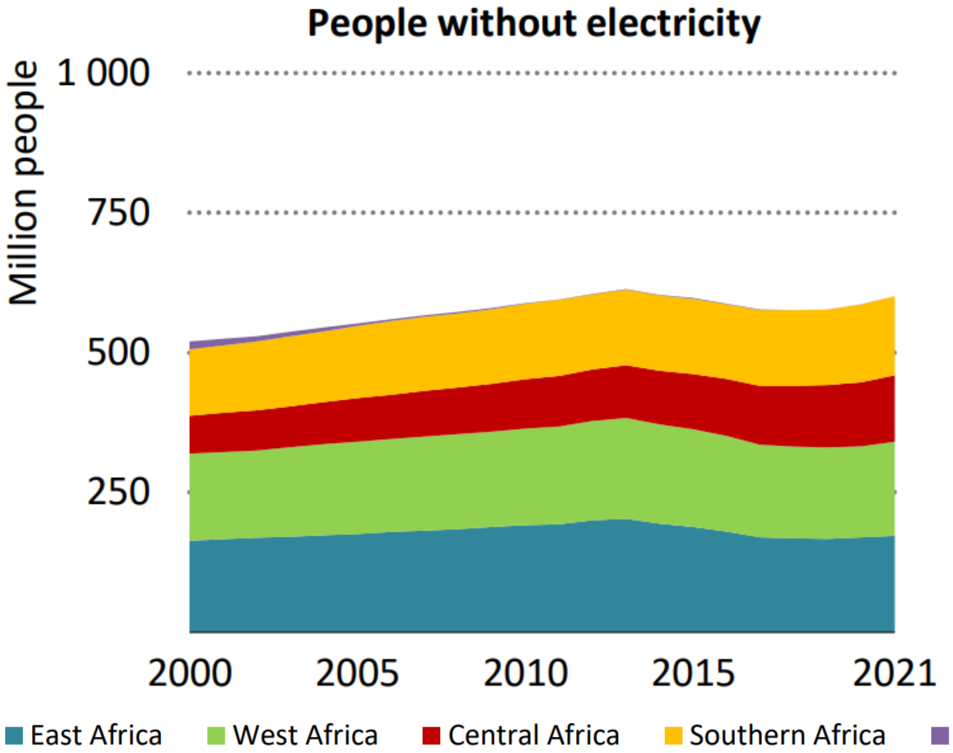
Lab Head IHL

Jennifer McKay

The Future and (Nuclear) Energy on the African Continent

Electricity access in Africa

Africa's low access to modern energy is undermining its development goals and ability to build climate resilience.



43% of African population (~600 million) lacked access to electricity in 2022, the vast majority in sub-Saharan Africa

Access varies across the continent.

20% of the world's population is in Africa, but accounts for only 6% of the global energy demand.

16 African countries considering nuclear power generation: Algeria, Burkina Faso, Egypt, Ethiopia, Ghana, Kenya, Morocco, Niger, Nigeria, Senegal, South Africa, Sudan, Tunisia, Uganda, Zambia, Zimbabwe

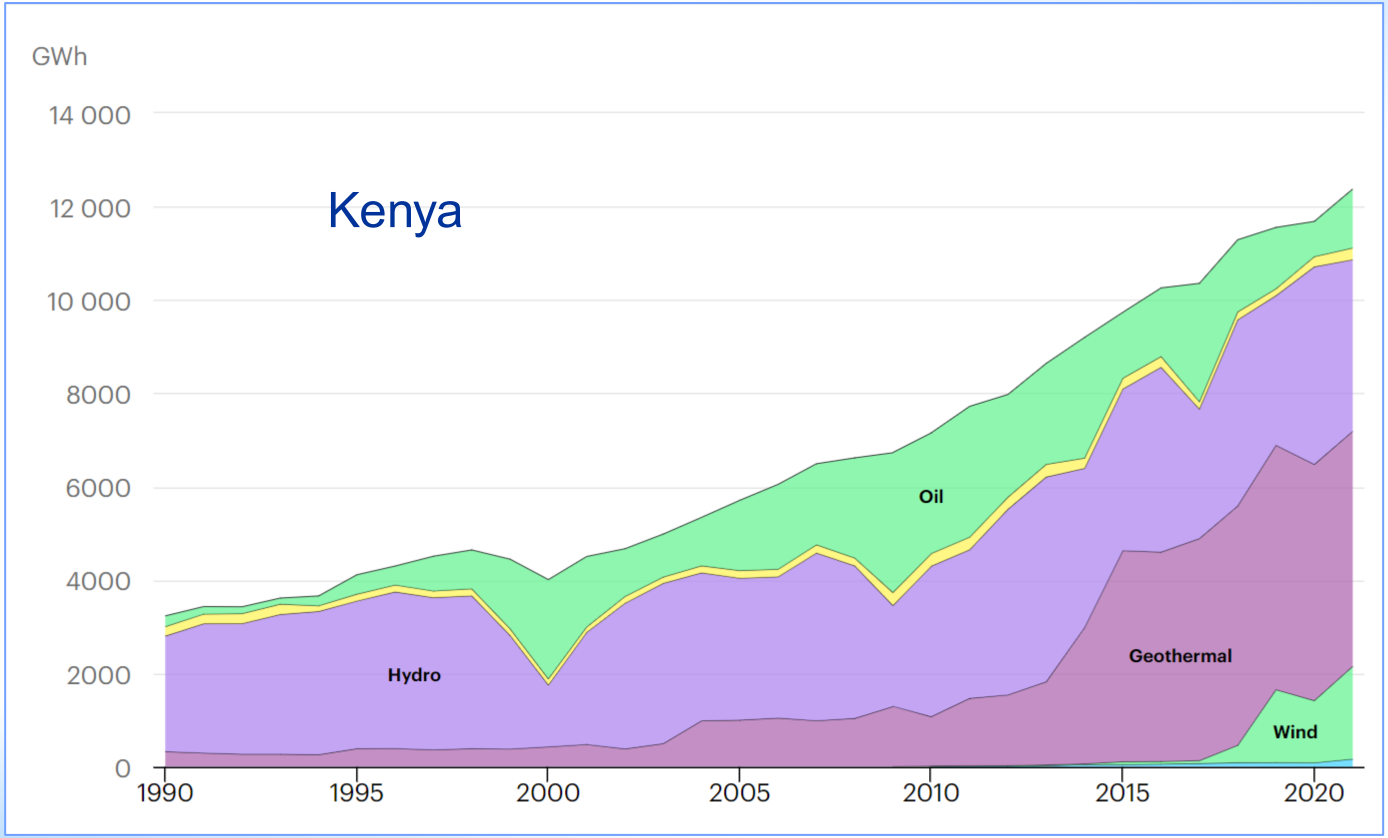
Africa suffers from a deficit in infrastructure investment

Biggest energy challenges for Africa

Achieving universal access, requiring

- Increased investment
- Shift to clean energy
- Renewal and extension of networks
- Balance export revenues with meeting indigenous needs

Electricity production by source, years 1990-2021



Geothermal energy in Africa

Expanding Kenya's Olkaria Geothermal Power Station

- East African Great Rift Valley with low surface coverage conducive to exploitation

- Kenya current thermal capacity = nearly 1 GW; planned capacity 1.6 GW in 2030, later 5 GW

Source https://www.dw.com/en/east-africas-new-love-affair-with-geothermal-energy/a-68088872

Solar energy

Africa has 60% of the world's solar resources

solar-powered solutions to energy needs include

Off-grid or mini-grid projects and

Very large infrastructure facilities

Clean Energy Drivers

IAEA

Health benefits of air pollution reduction is paramount.

The UN World Health Organization estimated in 2019 6.7 million premature deaths worldwide per year are caused by outdoor air pollution

Who Factsheet "Ambient (outdoor) air quality and health"; https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

Why Nuclear?
The Paris Agreement (CoP21) and IPCC

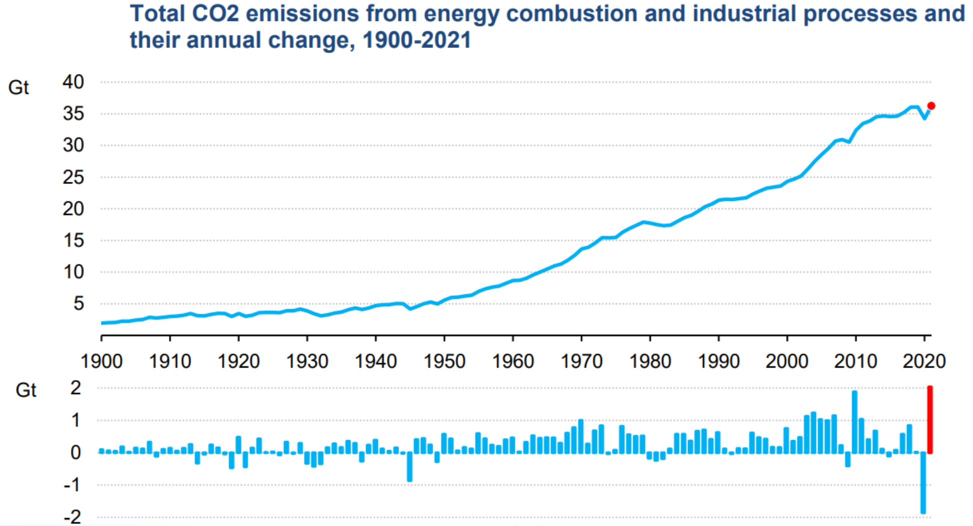
2°C Scenario (2DS) = concerted action to achieve >50% chance of limiting average global temperature increase to 2°C by 2100.

This requires:

- Reducing GHG emissions 25% from that in 2017 by 2030
- Energy sector offers the largest GHG reduction potential; projected reduction of cumulative 2015 - 2100 CO_2 emissions ~1,170 $GtCO_2$ (2021=36.3 $GtCO_2$)

But…

Total annual greenhouse gases emissions continue to reach record highs



Global Energy Review: CO2 Emissions in 2021, IEA

Roadmap to Net Zero

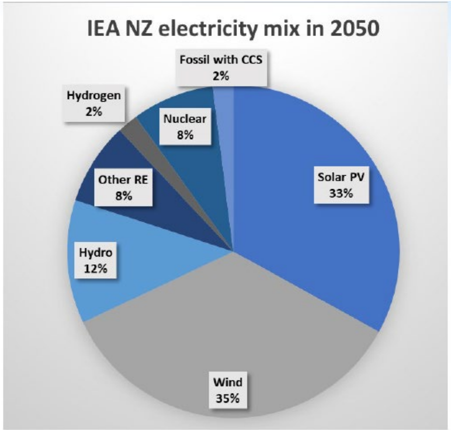
IAEA

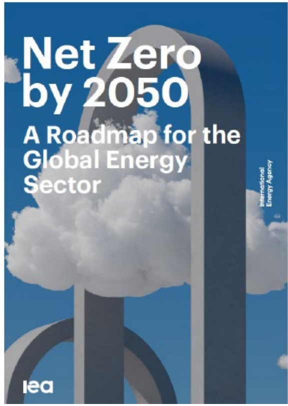
Net Zero=balance of anthropogenic GHG produced and that removed from the atmosphere

- Phase out fossil fuels
- Increase low-carbon renewables and nuclear (double present capacity by 2050)
- Innovate technologies

But…

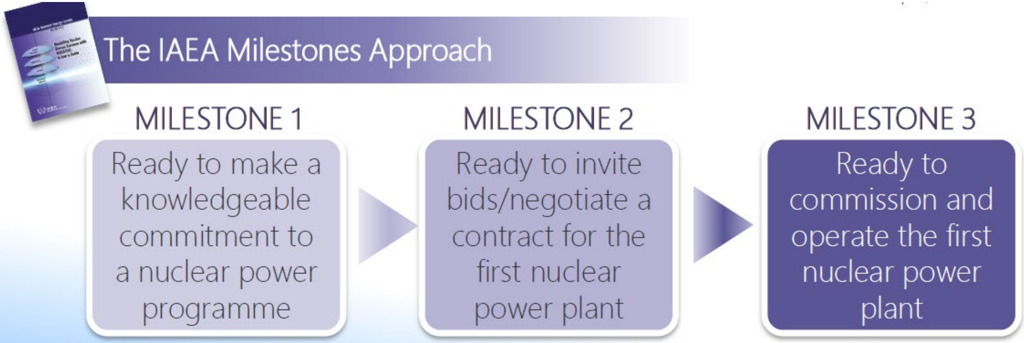
- ½ emission reductions projected rely on technologies not yet commercialized
- Supply of critical minerals is limited for massive increase in wind and solar capacity





African states with significant activity towards NPP

- Egypt: construction of 4.8 GW El Dabaa (4 units) NPP – first unit operational in 2028
- Kenya: siting at Kilifi and Kwale
- Nigeria: open for bidding for 4 GW
- South Africa: Seeking new nuclear to augment 1.9 GW at Koeberg



Nuclear energy is clean and low-C but what about the waste?

Waste is a relative burden

Non-hazardous solid waste generation per capita in Europe = 4.8 kg/day

www.alamy.com - EE11CY

EU-28 nuclear waste generation from electricity generation = 13.2 µg/day*

*24.7% from 3032.1 GWh generated in 2014, producing 0.82 ng waste/J electricity for a population of 508293.4 Mio

Sources:https://whatisnuclear.com/articles/waste_per_person.pdf
http://ec.europa.eu/eurostat/statistics-explained/index.php

Key issues in nuclear waste management

- Waste inventory
  - Early estimation of quantities, level of activity, other characteristics
  - Waste characterization and waste streams
- Waste minimization
  - Minimize waste generation
  - Recycle, reuse
  - Use low activation materials, etc.
- Mixed wastes
  - Account for non-radiological hazards and limitations
- Established disposal pathway for radioactive and other hazardous waste

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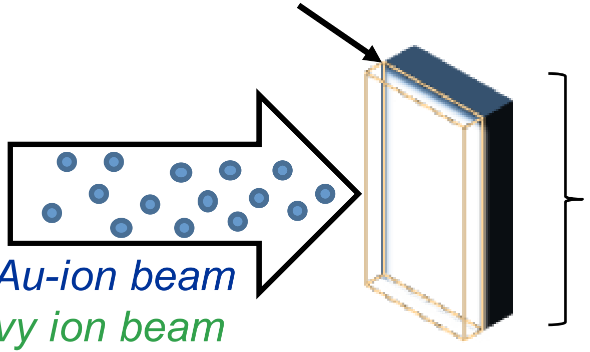
R&D and the nuclear fuel cycle

Two examples:

- accelerators for waste R&D
- non-destructive testing (NDT) for waste characterisation

IAEA CRP(F11022): INWARD

- Ion Beam Irradiation for High-Level Nuclear Wasteform Development – knowledge of ceramic and glass wasteform damage from self-irradiation by studying accelerated damage induced by ion beams



Comparison to An-doped, aged samples
Dose rate effects?
Critical dose for amorphization?
Leaching behaviour?
Characterisation: XRD, RBS, Raman, UV-Visible, XPS, XANES, AFM, nanoindentation, TEM, EELS

cf. CRP SMoRE-II: Ion beam irradiation as a proxy for accelerated reactor materials testing

Outcomes and motivation

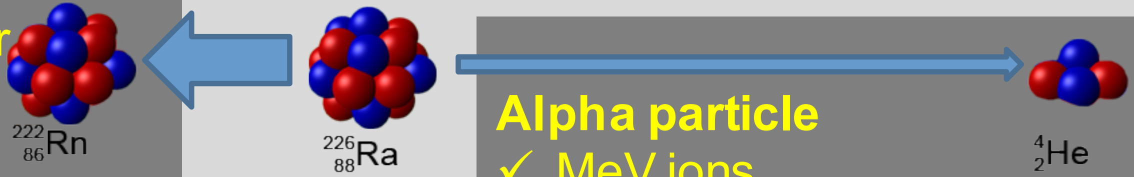
Confidence in using ion beam irradiation for predicting long-term performance of wasteforms for safe containment of high level nuclear waste through:

- Understanding damage evolution in candidate waste forms
- Comparison of ion-irradiated and natural/historical samples
- Intercomparison of dual beam vs single beam (alpha and recoil emulation)
- Development of protocols for future studies

Alpha decay damage in materials

Alpha-recoil nucleus:

- ✓ keV ions - more nuclear collisions
- ✓ nm Range
- ✓ More damage (thousands of atoms displaced)

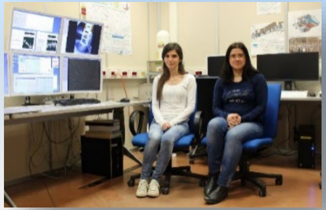


Alpha particle

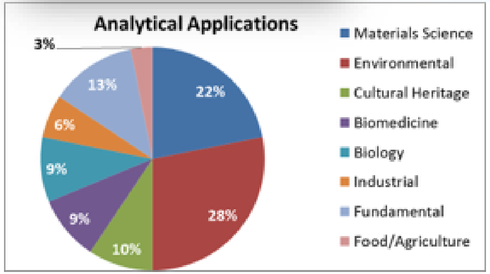
- ✓ MeV ions
- ✓ μm Range
- ✓ Less damage (hundreds of atoms displaced)

+Helium accumulation

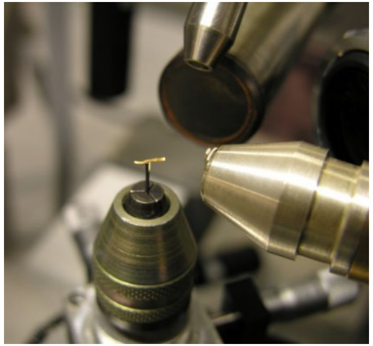
Facilitated access to state-of-the-art accelerator facilities



- IAEA-ELETTRAjoint XRF beamline (since 2013)
  - Dedicated beam-time for IAEA; >20 groups from >18 MSs
  - Recent improvements of the beam line and end-station
  - UHVC 'Mirror Facility' for training commissioned at NSIL Seibersdorf
  - TR workshop at SESAME, with remote connection to ELETTRA in 2018



- IAEA-RBI agreement (collaboration >20 years)
  - New ion source for dual beam capability commissioned
  - TR workshop, with hands-on-training using various ion beam techniques
  - New CRP to facilitate experiments at ion beam facilities started
  - TR workshop at Seibersdorf, with remote connection to RBI in 2018



Non-destructive testing for waste characterisation, e.g. muon radiography

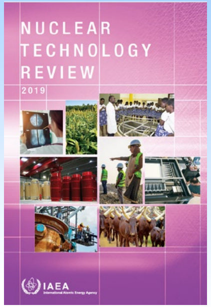
Future CRP **Non-destructive Testing Using Muon Radiography**

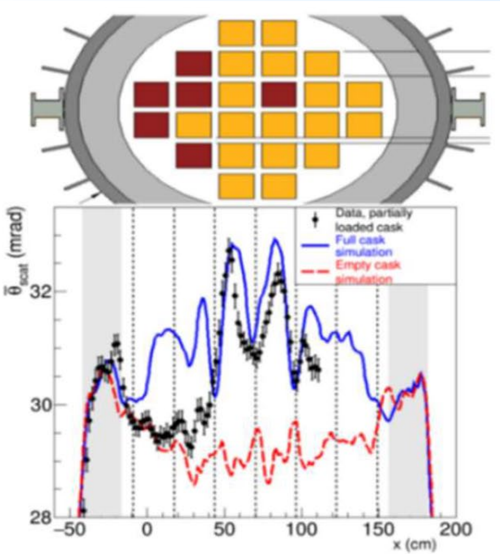
Muon radiography uses cosmic ray muons as a source, instead of gammas, X-rays or neutrons.

Advantages:

- Highly penetrating
- Transmission detects density differences and scattering Z (scattering=f($1/Z^2$))

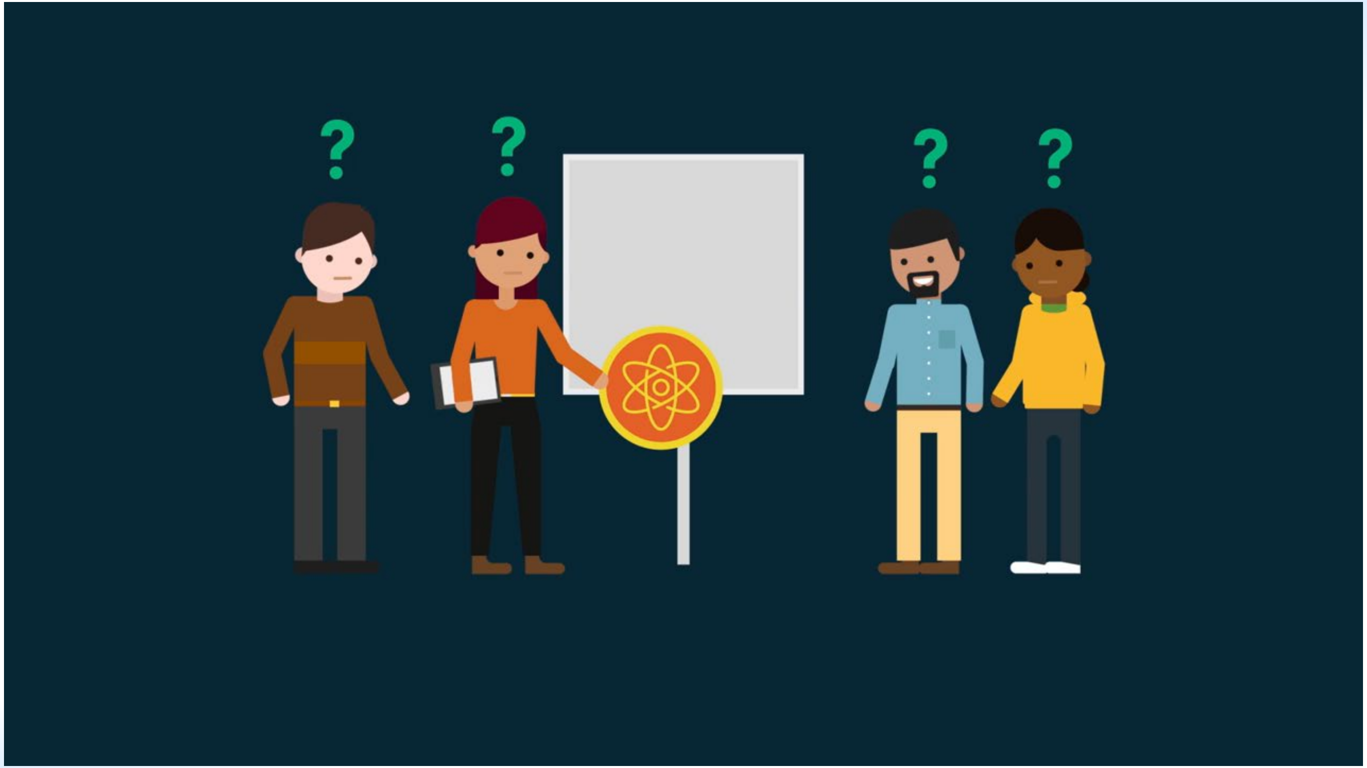
Muon radio(tomo)graphy for waste package characterisation





- Applicable for waste confined in containment materials and encasements
- Can distinguish between nuclear fuel and other metals
- Usable for dray cask storage and legacy wastes
- Demonstrator used at Sellafield
- Can image corium and reactor debris in Fukushima Daichi reactors

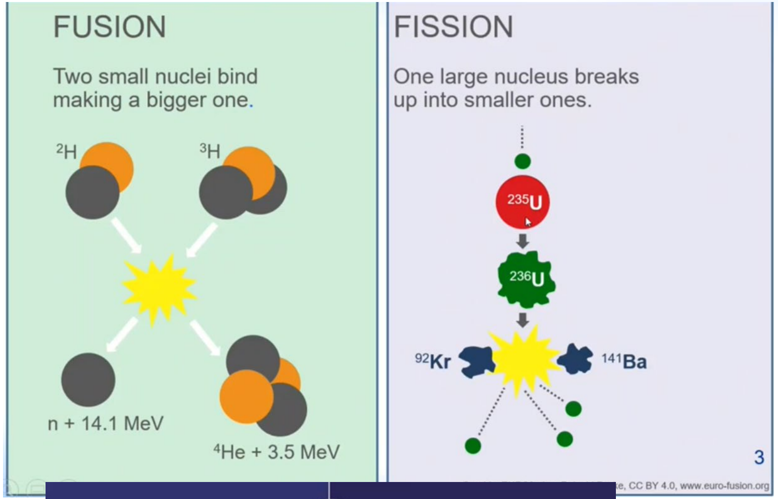
What might the future look like?
Fusion Energy Research

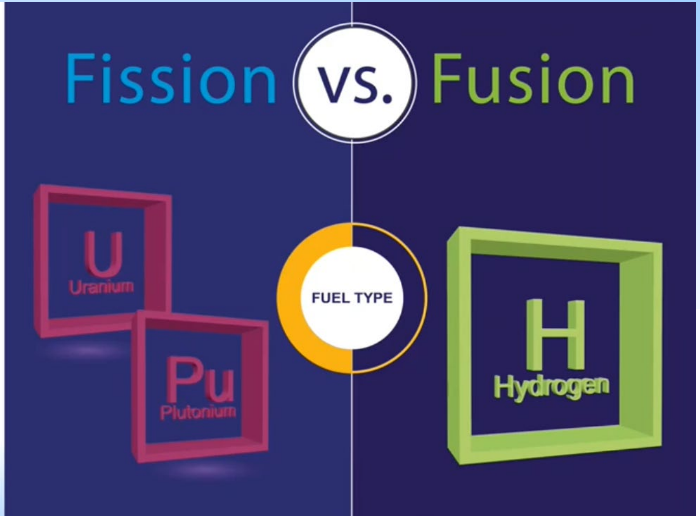


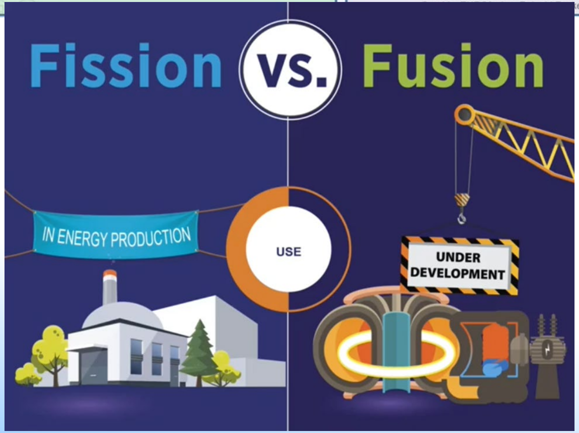
Why is fusion needed and what benefits does fusion bring ?

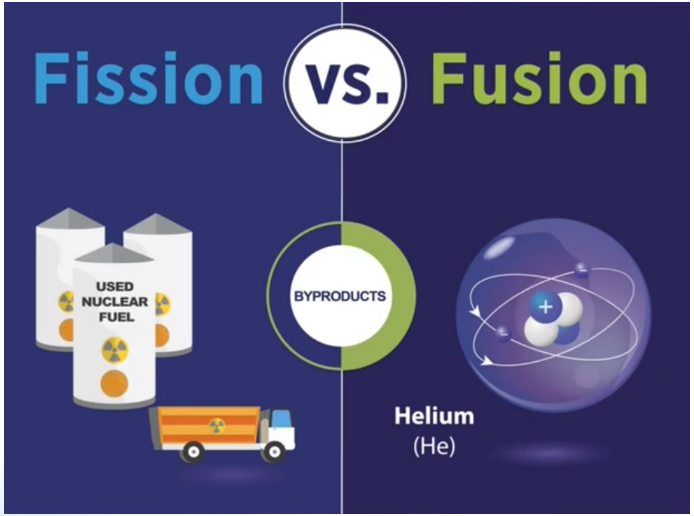
- The energy consumption increases ~ 0.2 GW each year
- Fusion has a potential of providing inexhaustible source of energy without danger or CO_2 emissions

Fusion versus Fission









MERITS OF FUSION

Carbon free
Zero gas emission

Virtually clean

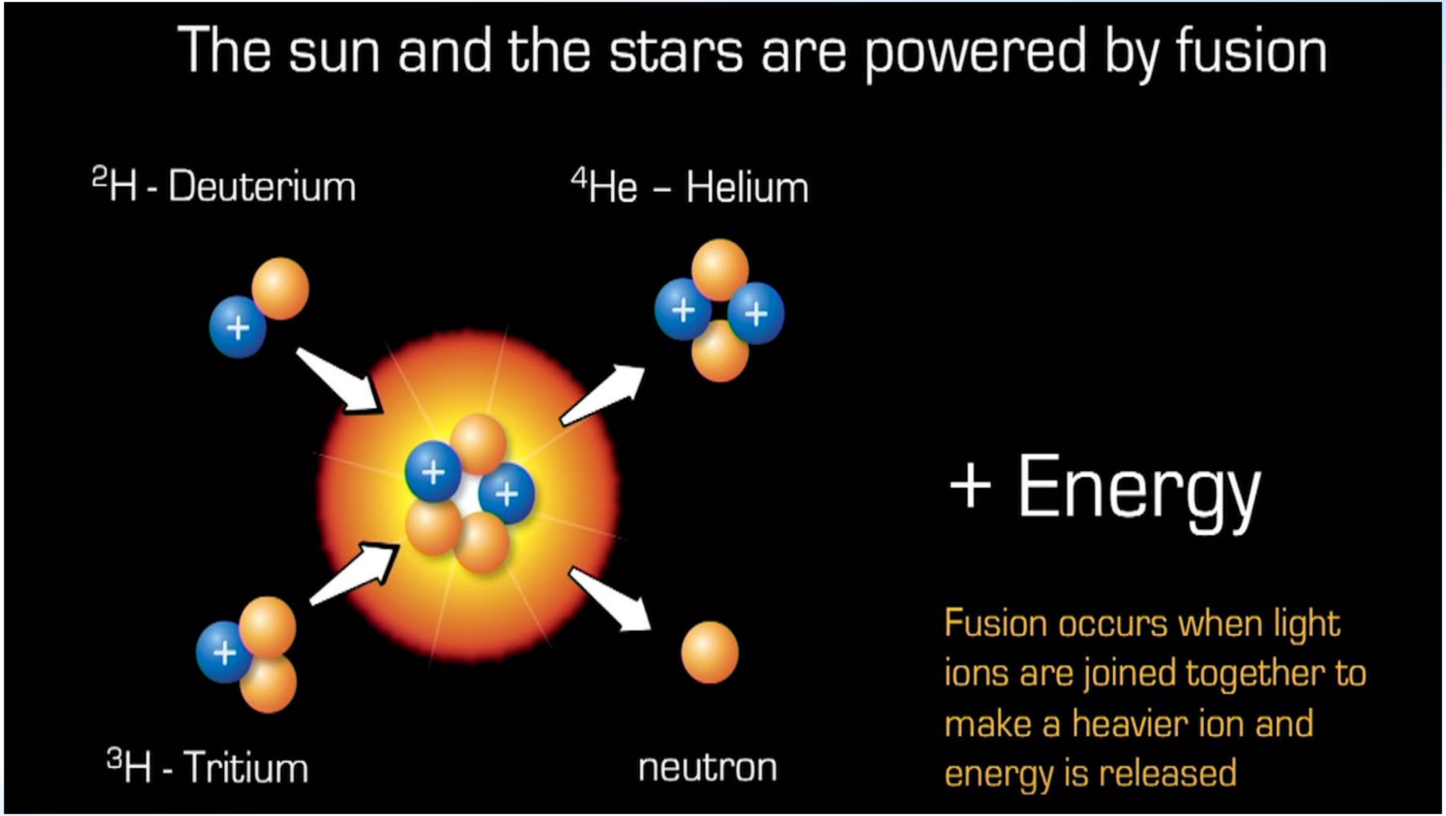
Low level, manageable waste
No long-lived radioactive waste production

Inherently safe
No chain reaction

Unlimited fuel

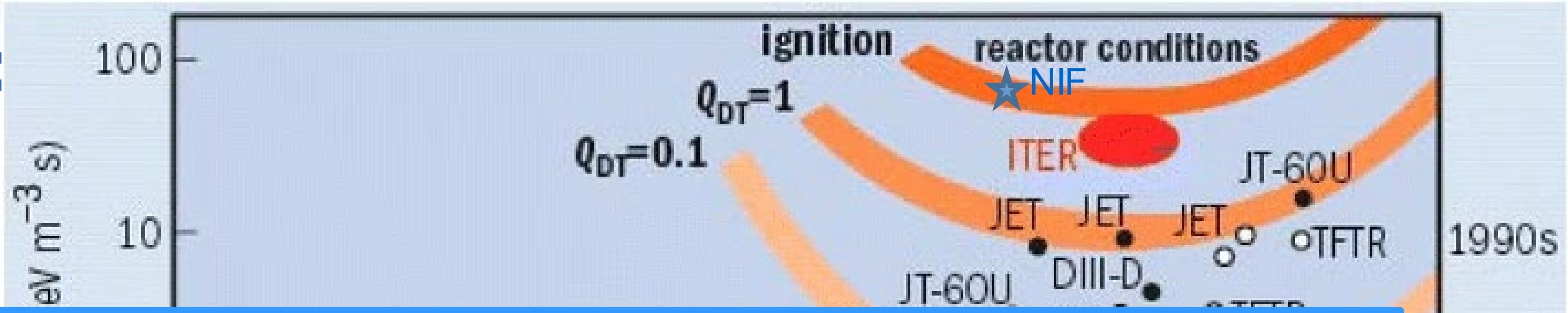
Reliable

Fusion: Introduction



$D + T \rightarrow {}^4He\ (3.5\ MeV) + n\ (14.1\ MeV)$

F



PHYSICAL REVIEW LETTERS **129**, 075001 (2022)

Editors' Suggestion | Featured in Physics

Lawson Criterion for Ignition Exceeded in an Inertial Fusion Experiment

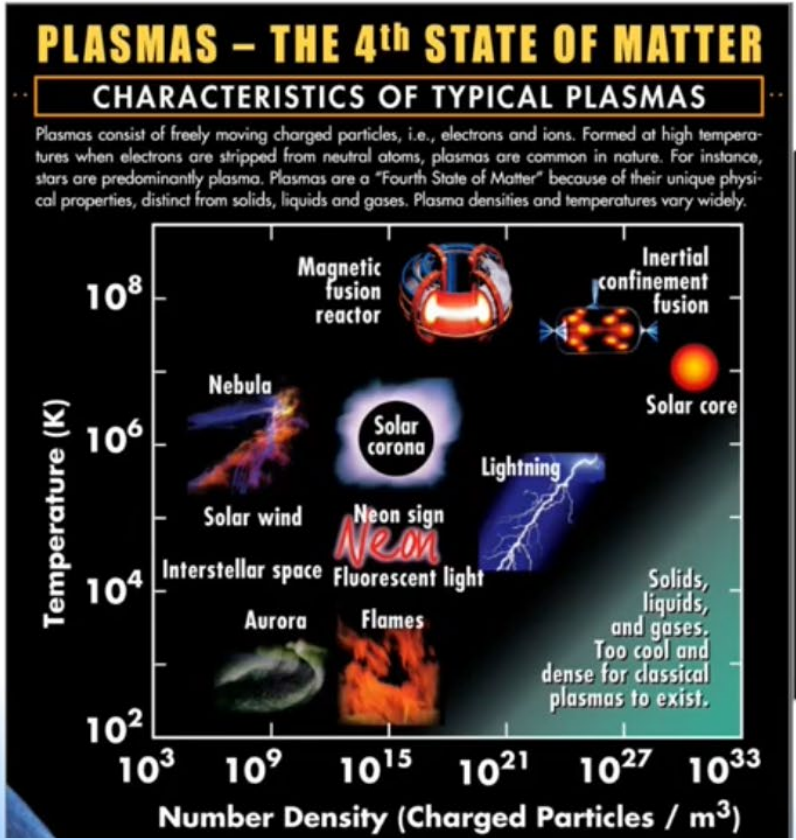
H. Abu-Shawareb *et al.*[*]
(Indirect Drive ICF Collaboration)

(Received 25 February 2022; revised 24 June 2022; accepted 6 July 2022; published 8 August 2022; corrected 16 August 2022)

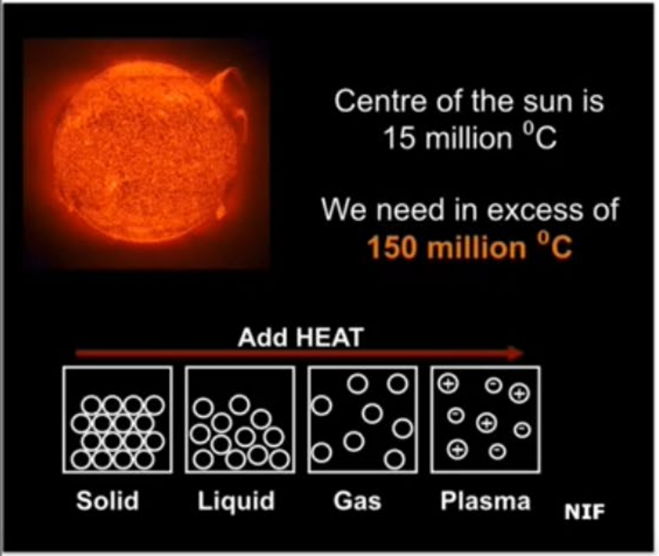
For more than half a century, researchers around the world have been engaged in attempts to achieve fusion ignition as a proof of principle of various fusion concepts. Following the Lawson criterion, an ignited plasma is one where the fusion heating power is high enough to overcome all the physical processes that cool the fusion plasma, creating a positive thermodynamic feedback loop with rapidly increasing temperature. In inertially confined fusion, ignition is a state where the fusion plasma can begin "burn propagation" into surrounding cold fuel, enabling the possibility of high energy gain. While "scientific breakeven" (i.e., unity target gain) has not yet been achieved (here target gain is 0.72, 1.37 MJ of fusion for 1.92 MJ of laser energy), this Letter reports the first controlled fusion experiment, using laser indirect drive, on the National Ignition Facility to produce capsule gain (here 5.8) and reach ignition by nine different formulations of the Lawson criterion.

DOI: 10.1103/PhysRevLett.129.075001

Learning from the Sun – PLASMA

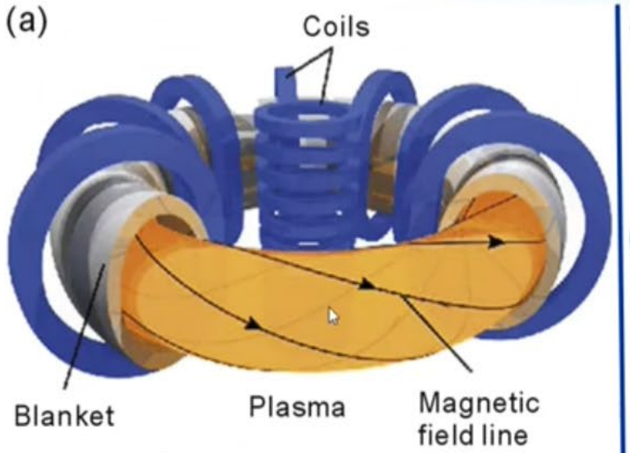


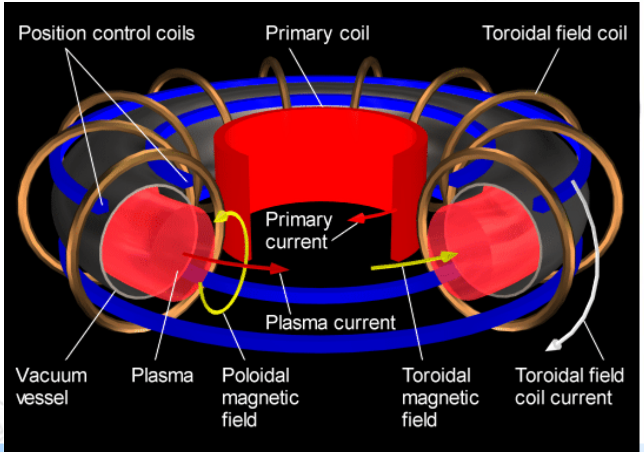
More than 99% of the Universe exists as plasma, including interstellar matter, stars and the Sun.



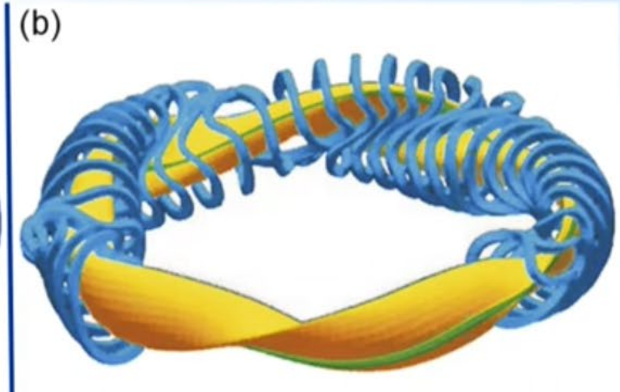
Tokamaks and Stellarators

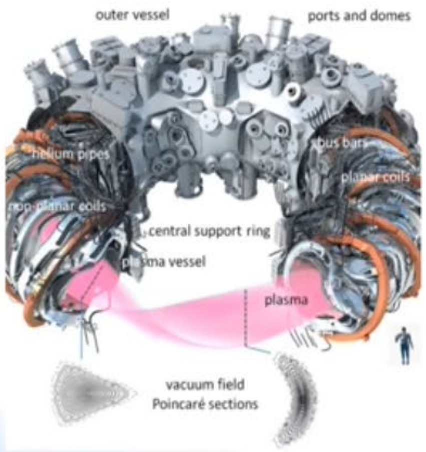
Tokamak



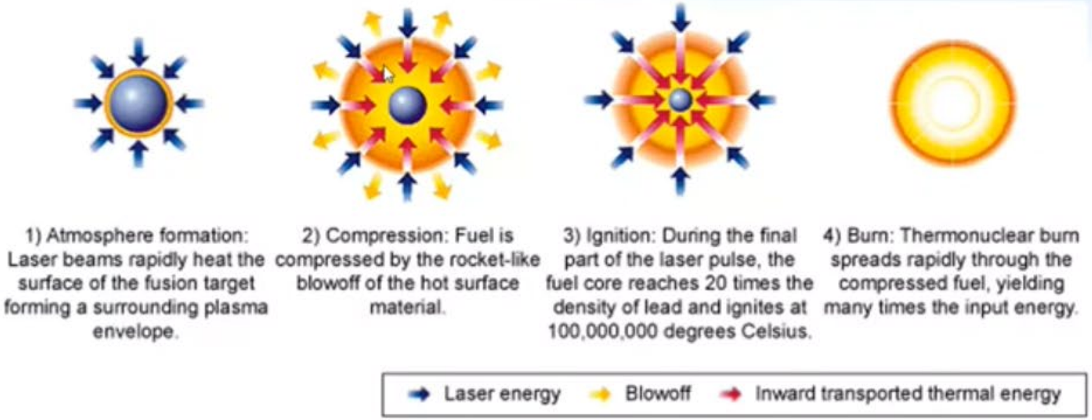


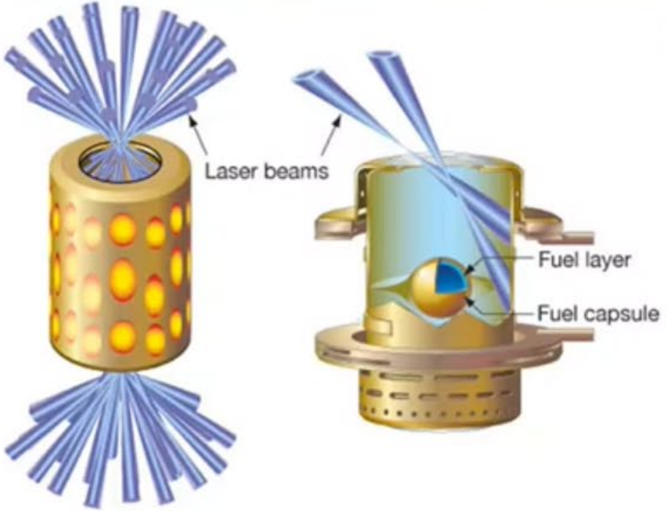
Stellarators





Inertial Confinement Fusion (ICF)





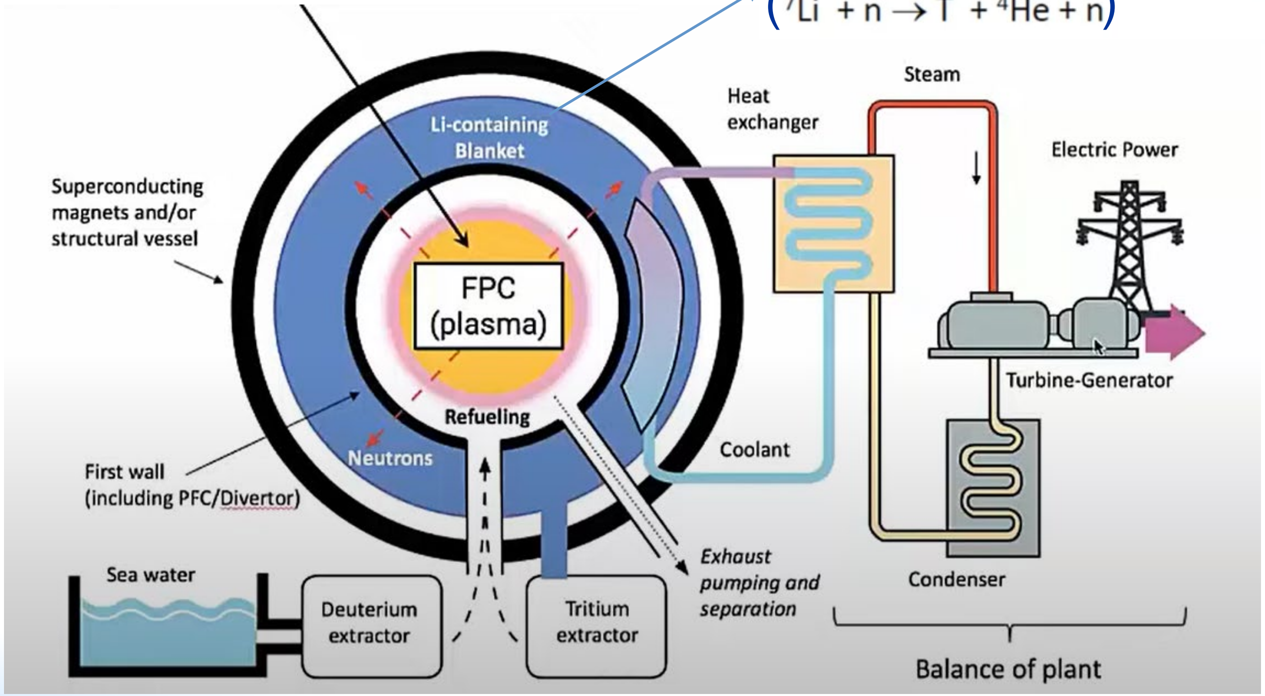
- Fuel is compressed and heated so quickly that it reaches the conditions for fusion and burns before it has time to escape
- Fuel: few milligrams of a mixture of deuterium and tritium—in solid form this is a small spherical pellet, or capsule, with a radius of a few millimetres.

All of the energy of NIF's 192 beams is directed inside a gold cylinder called a hohlraum, which is about the size of a dime. A tiny capsule inside the hohlraum contains atoms of deuterium and tritium that fuel the ignition process.

Fusion Energy and D-T Fusion Fuel Cycle

$$^{6}Li + n \rightarrow T\ (2{,}7\ MeV) + {}^{4}He\ (2{,}1MeV)$$

$$({}^{7}Li + n \rightarrow T + {}^{4}He + n)$$



Credits: S. Hsu (ARPA-E, 2021)

- Tritium is not defined as a "nuclear material" by the IAEA and therefore not covered by nuclear safeguards
- In principle, fusion facilities fall outside the definition of "nuclear installation or nuclear facility"

Fusion Research: ITER

A GIANT

23000 t

Machine weight

10X THE CORE OF THE SUN

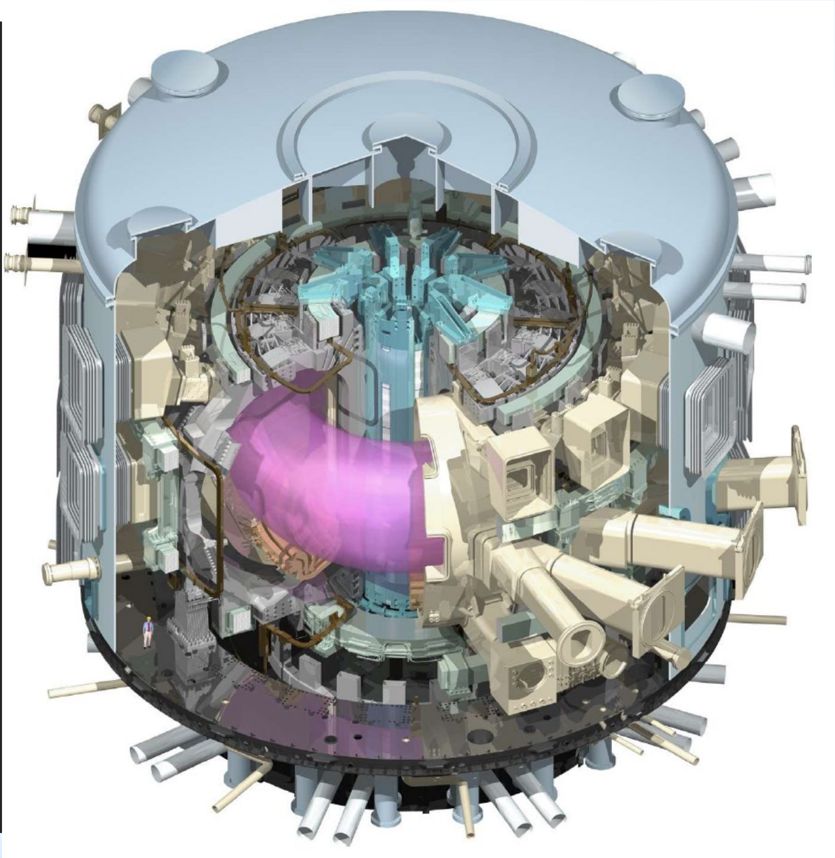
150 million°C

Plasma temperature

FUSION ENERGY

500 MW

Output power



- 35 ITER Member States: EU + Switzerland, China, Korea, Japan, India, Russia, USA
- demonstrate feasibility of large scale fusion power
- Input (heating) 50 MW → Output (thermal) 500 MW for 400 seconds
- ITER schedule:
  - –Under construction in South of France, 77% complete
  - –First Plasma in December 2025 (?) and DT Operation in 2035 (?)

ITER under construction

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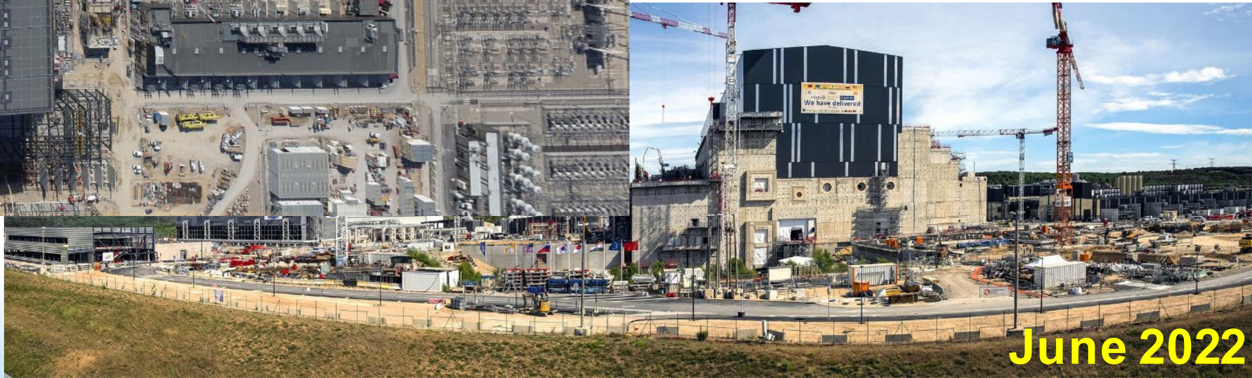
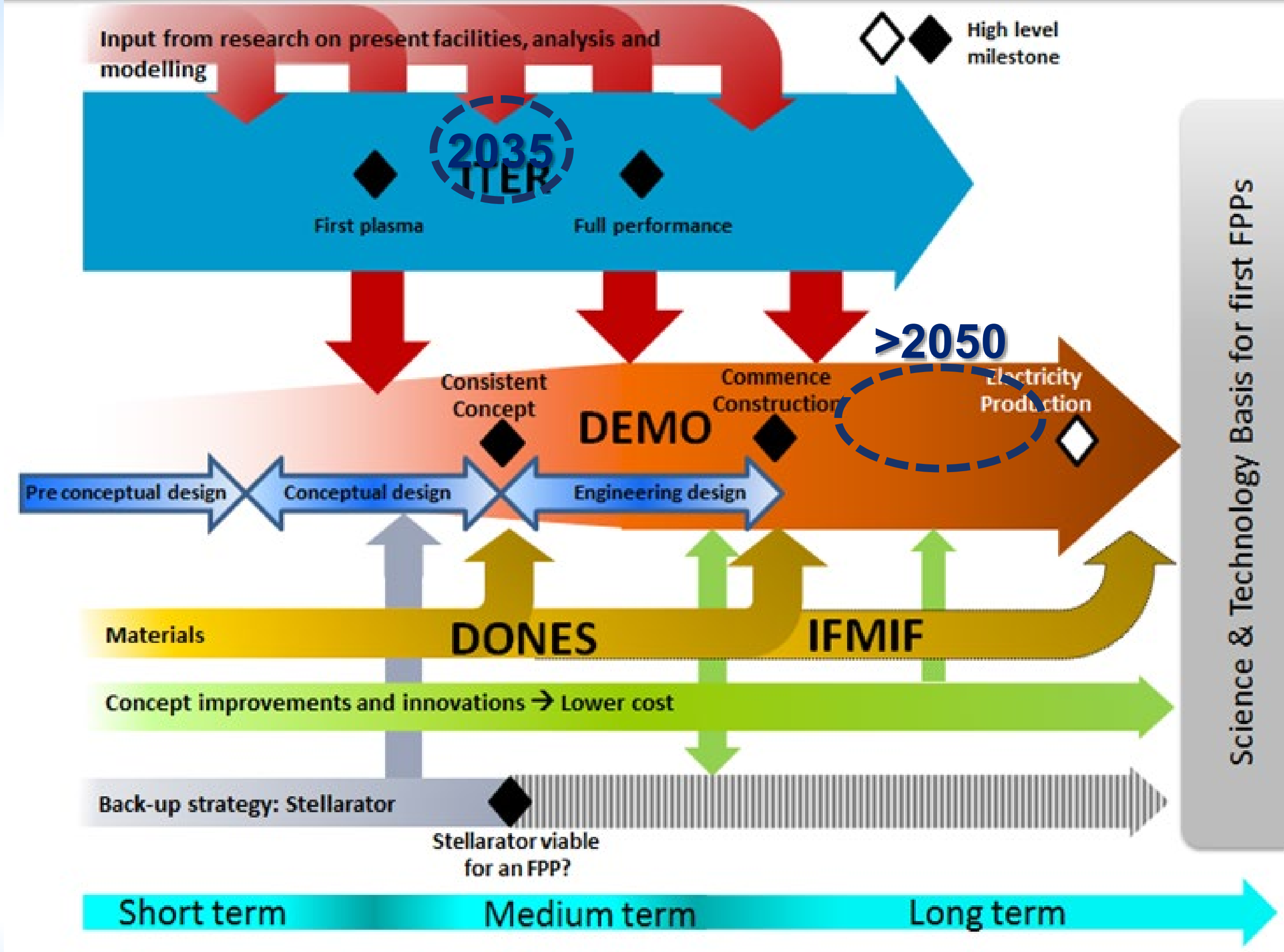


Fusion Roadmap

Main challenges:

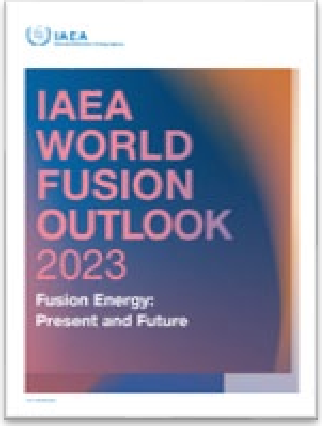
- Real-time plasma control (Disruptions)
- Heat exhaust and helium removal (Divertor)
- Plasma Environment – the Materials Challenge
- Design Integration
- Tritium-breeding blanket (coolant, plant balance)
- Remote maintenance development

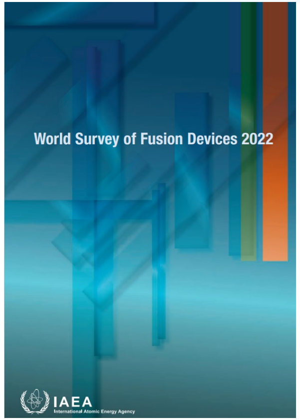


Source: Fusion For All – DONES (ifmifdones.org); See European Research Roadmap to the Realisation of Fusion Energy, 2018

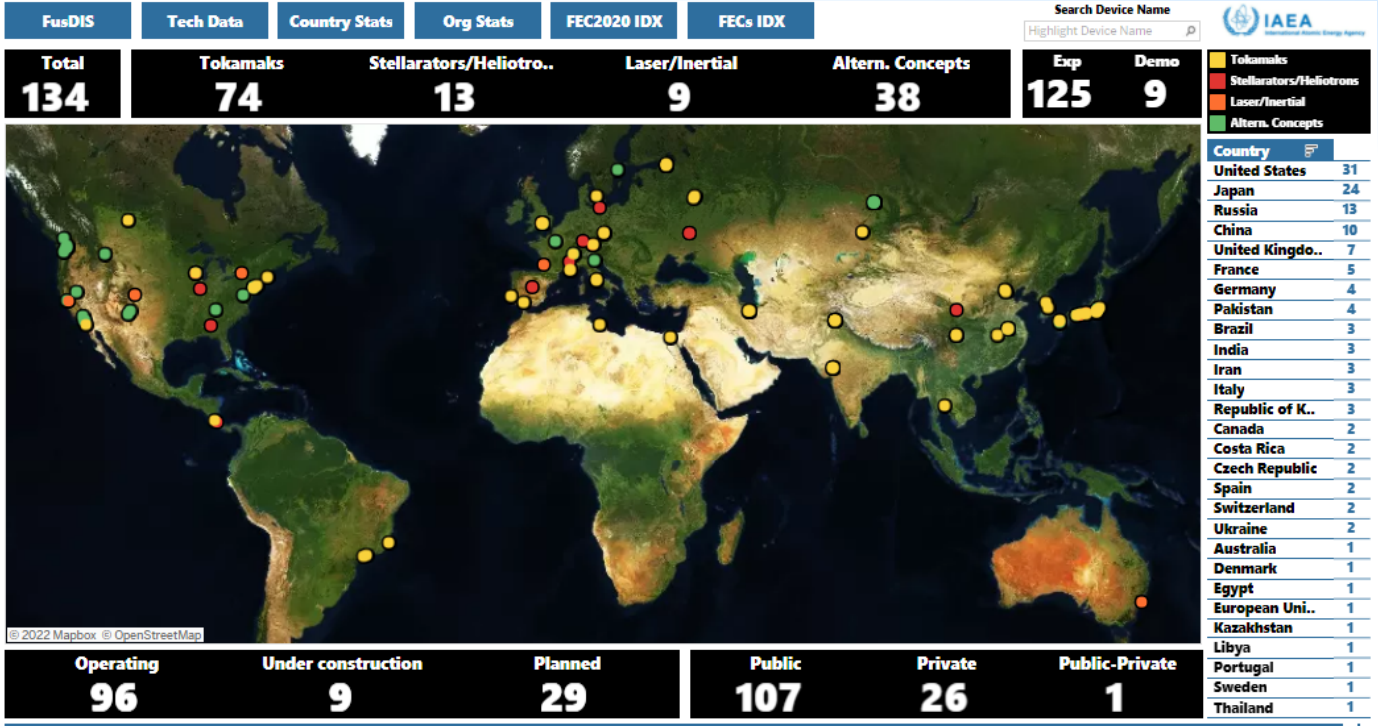
Fusion at IAEA

1. Plasma related activities
2. Nuclear Data https://amdis.iaea.org/
3. Development of International Guidelines and Standards for Fusion Applications:
   - Safety and Security for Fusion Applications
   - RadWaste Management for Fusion Applications
   - Small Specimens Test techniques
4. Inertial Fusion and neutron source related activities
5. Socioeconomic studies
6. Leading events in Fusion
   - Fusion Energy Conference
   - DEMO Programme Workshop series
7. Nuclear Fusion Journal
8. Events in cooperation. Education & training
9. Fusion Portal and the Fusion Device Information System (FusDIS)





Fusion Device Information System (FusDIS)



https://nucleus.iaea.org/sites/fusionportal/Pages/FusDIS.aspx

IAEA Fusion Energy Conference 2023

30th IAEA Fusion Energy Conference (FEC2025)

13th to 18st October 2025

Background

The International Atomic Energy Agency (IAEA) fosters the exchange of scientific and technical results in nuclear fusion research and development through its series of Fusion Energy Conferences.

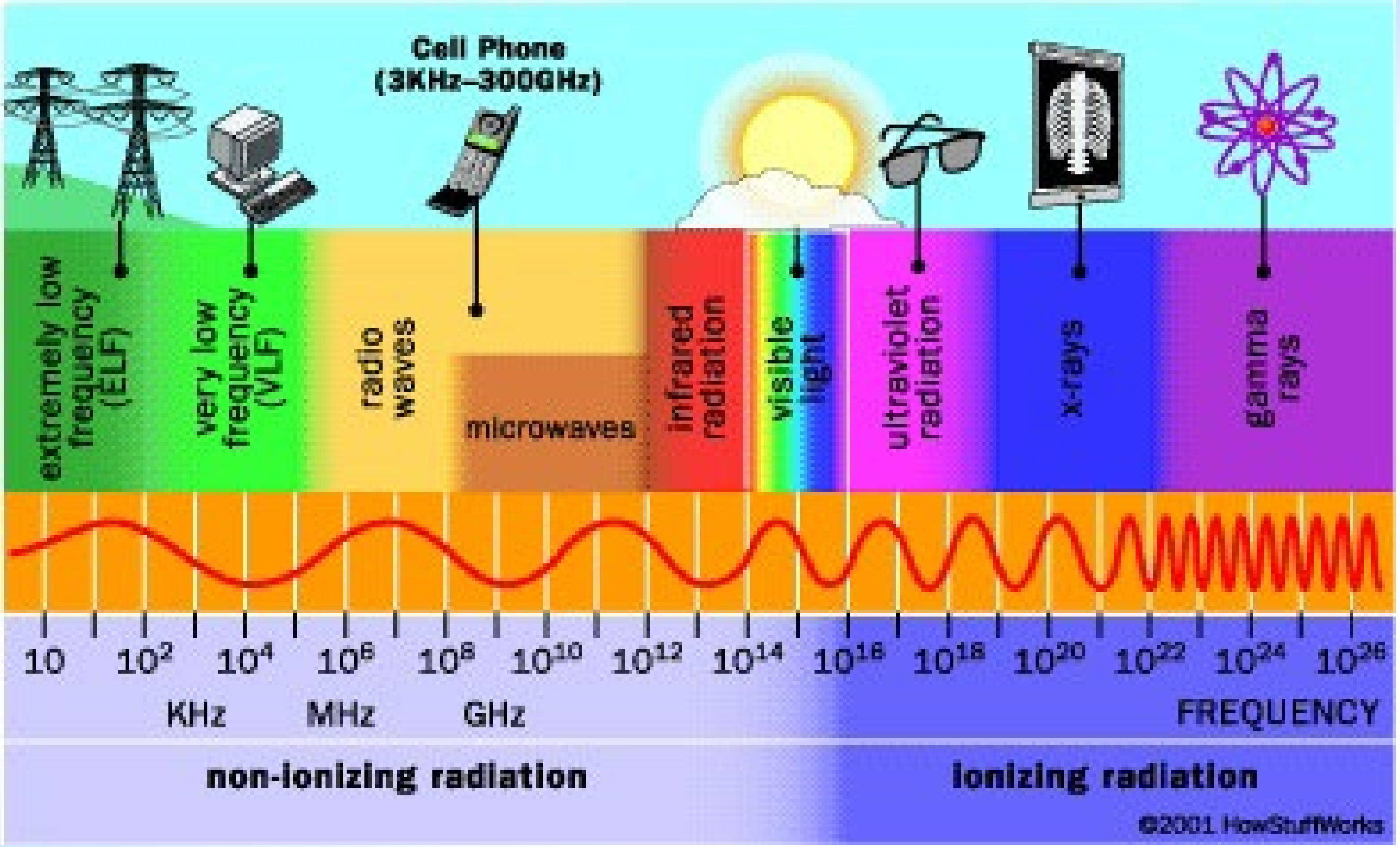
The 29th IAEA Fusion Energy Conference (FEC 2023) aims to provide a forum for the discussion of key physics and technology issues as well as innovative concepts of direct relevance to the use of nuclear fusion as a future source of energy.

The scope of FEC 2023 is, therefore, intended to reflect the priorities of this new era in fusion energy research, technology development and preparation to industrial deployment. The conference aims to serve as a platform for sharing the results of research and development efforts in both national and international fusion experiments that have been shaped by these new priorities, and to thereby help in pinpointing worldwide advances in fusion theory, experiments, technology, engineering, materials, advanced concepts, safety, socio-economics and preparation to industrial deployment. Furthermore, the conference will also set these results against the backdrop of the requirements for a net energy-producing fusion device and a fusion power plant in general, and will thus help in defining the way forward.

Related Resources

- Announcement and Call for Papers
- How to Register for an IAEA Conference/Symposia
- InTouch+ Platform
- IAEA-INDICO (Paper Submissions)
- FAQ

Types of radiation



TYPES OF RADIATION

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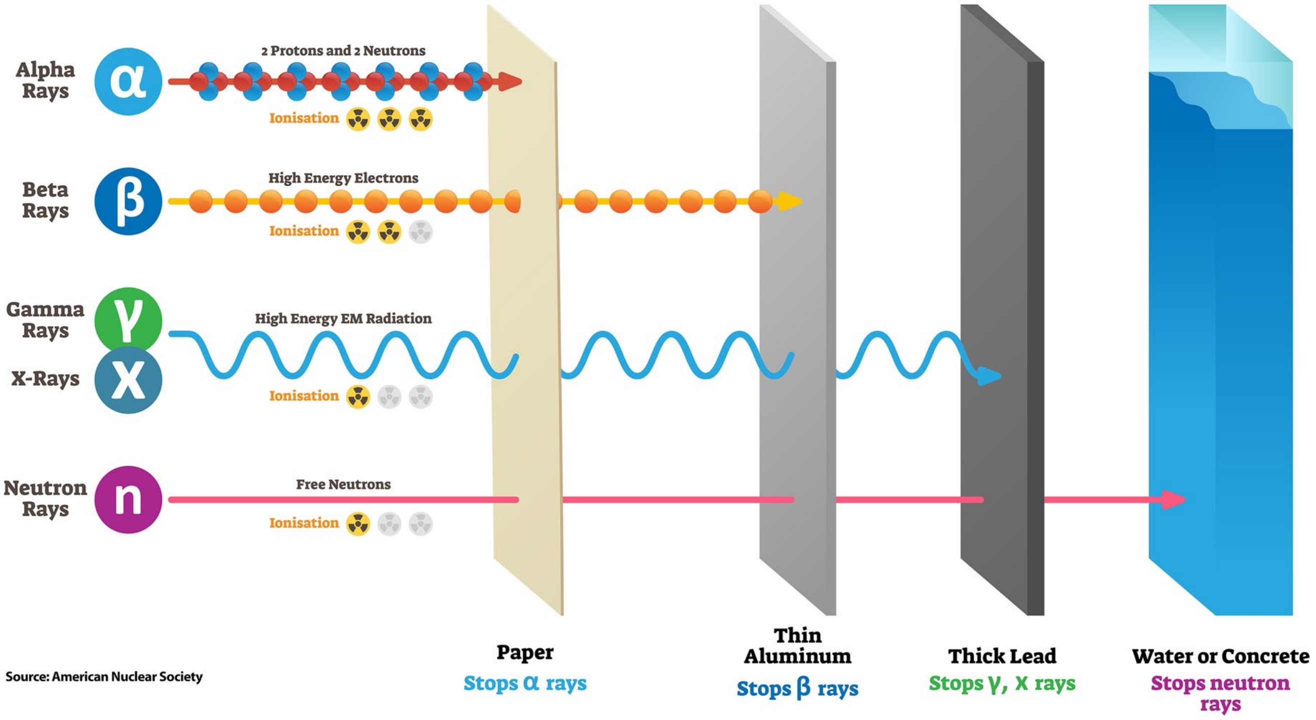
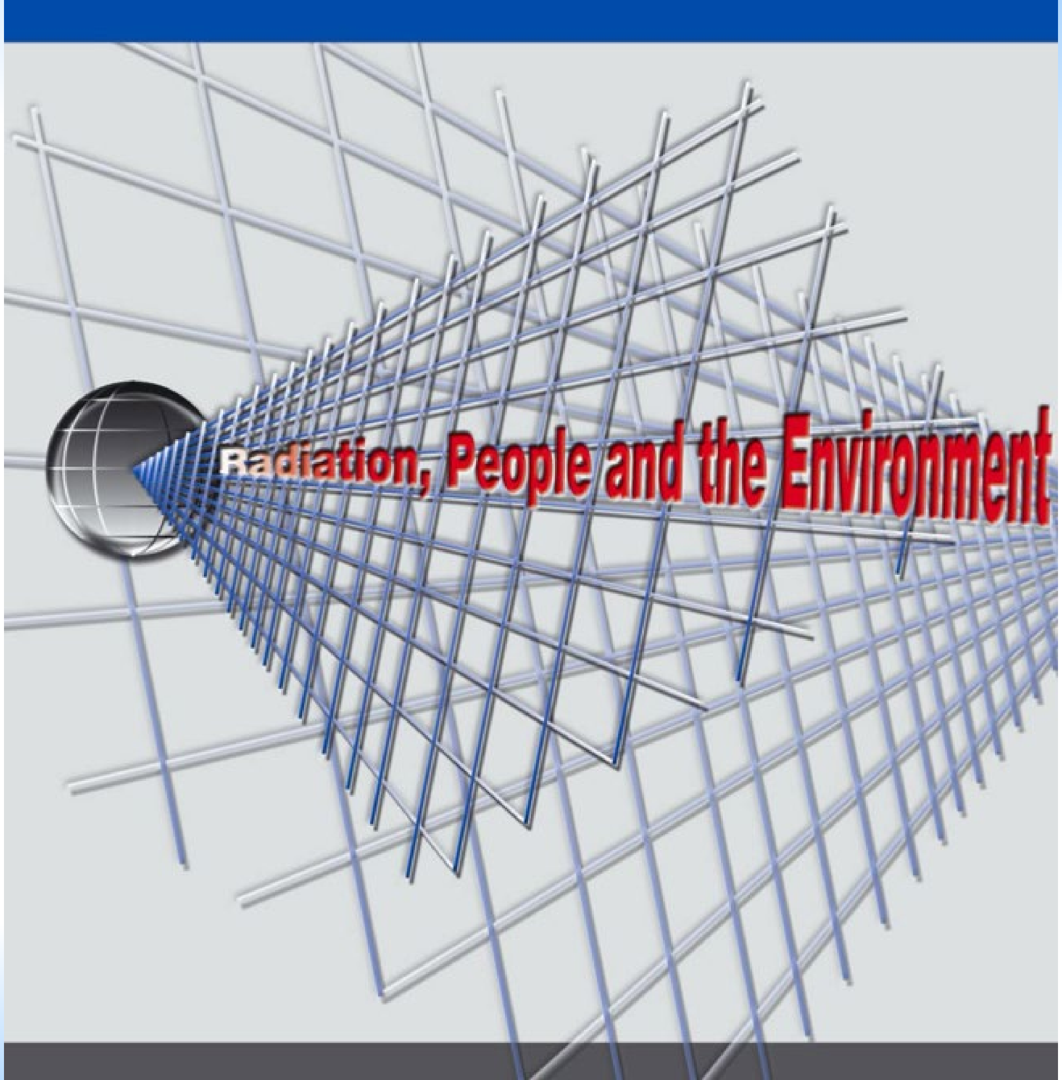


Source: American Nuclear Society


Radiation, People and the Environment

CONTENTS

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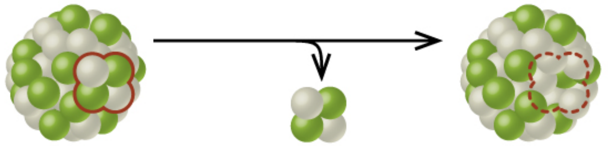
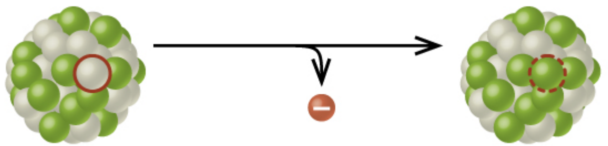
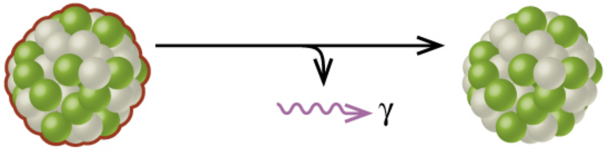
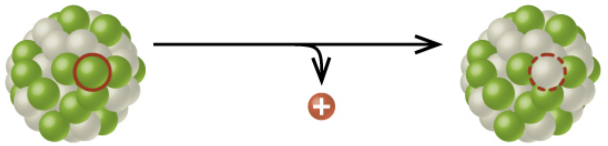
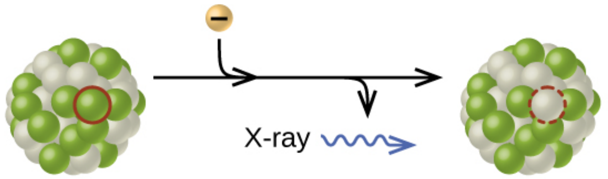
Some important definitions

Radionuclides	*Unstable nuclides*
Radioactivity	*Emission of radiation*
Radiation types	*Alpha, beta, gamma, neutron, and X ray*
Activity	*Decay rate of radionuclide*
Half-life	*Time to half activity*

Decay of an excited nucleus

Type	Nuclear equation	Representation	Change in mass/atomic numbers
Alpha decay	$^{A}_{Z}X$ $\quad$ $^{4}_{2}He + ^{A-4}_{Z-2}Y$		A: decrease by 4 Z: decrease by 2
Beta decay	$^{A}_{Z}X$ $\quad$ $^{0}_{-1}e + ^{A}_{Z+1}Y$		A: unchanged Z: increase by 1
Gamma decay	$^{A}_{Z}X$ $\quad$ $^{0}_{0}\gamma + ^{A}_{Z}Y$		A: unchanged Z: unchanged
Positron emission	$^{A}_{Z}X$ $\quad$ $^{0}_{+1}e + ^{A}_{Y-1}Y$		A: unchanged Z: decrease by 1
Electron capture	$^{A}_{Z}X$ $\quad$ $^{0}_{-1}e + ^{A}_{Y-1}Y$		A: unchanged Z: decrease by 1

Nuclear reactions have/will change(d) the world

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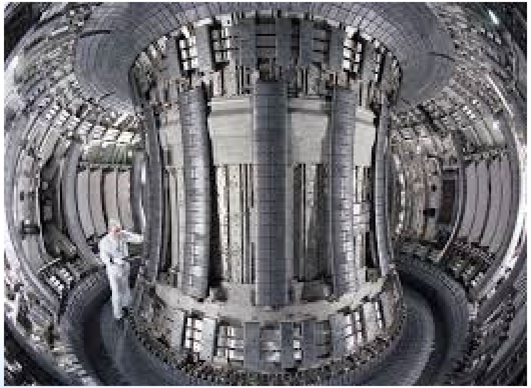
Nuclear weapons

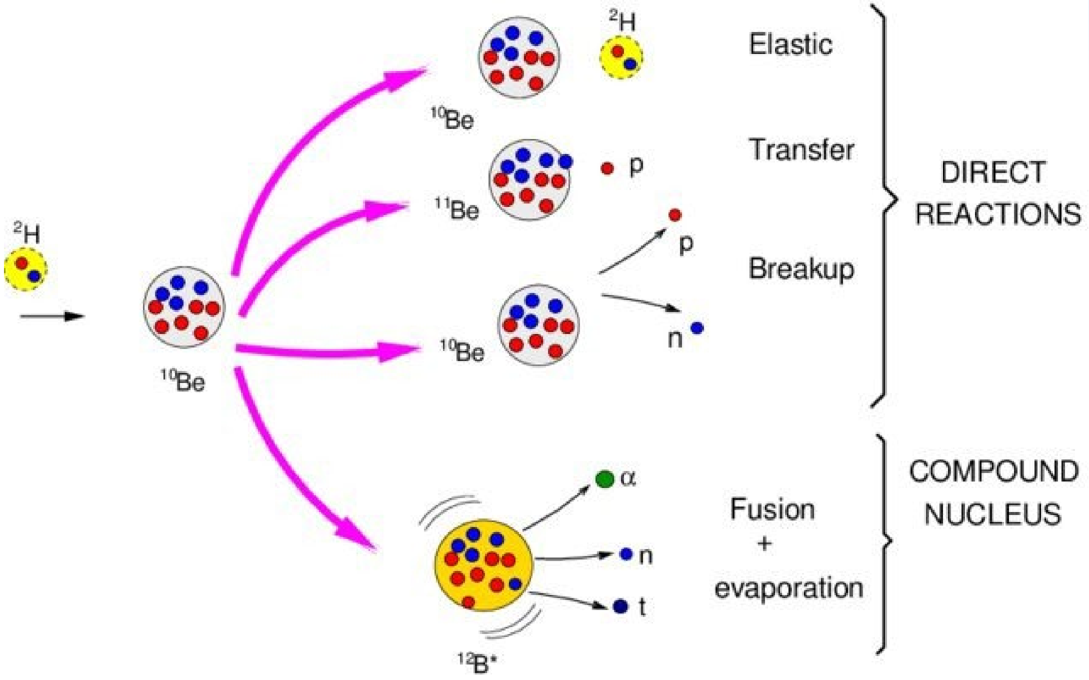
Nuclear energy

Medical isotopes



Nuclear fusion

Nuclear reaction

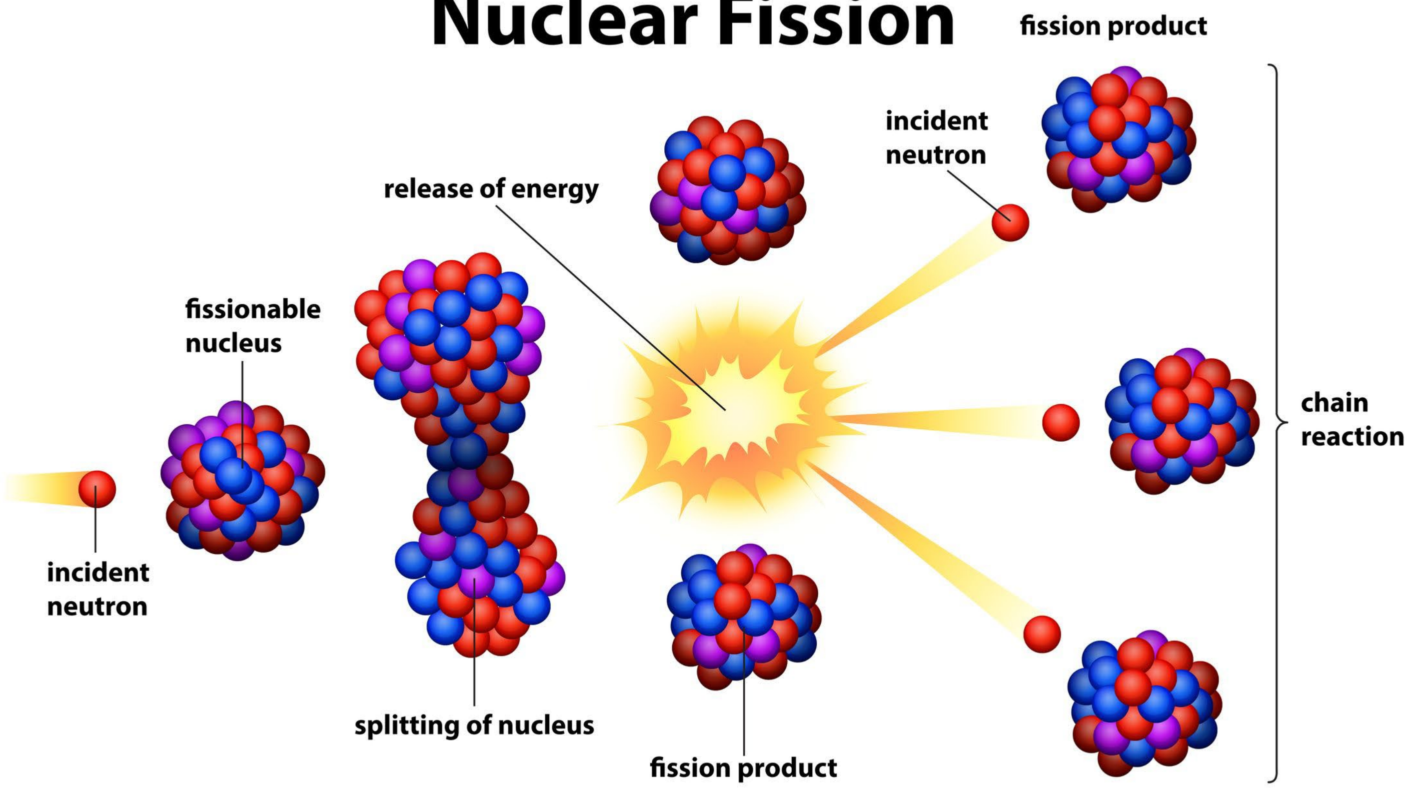


Fast: 10^{-21} sec

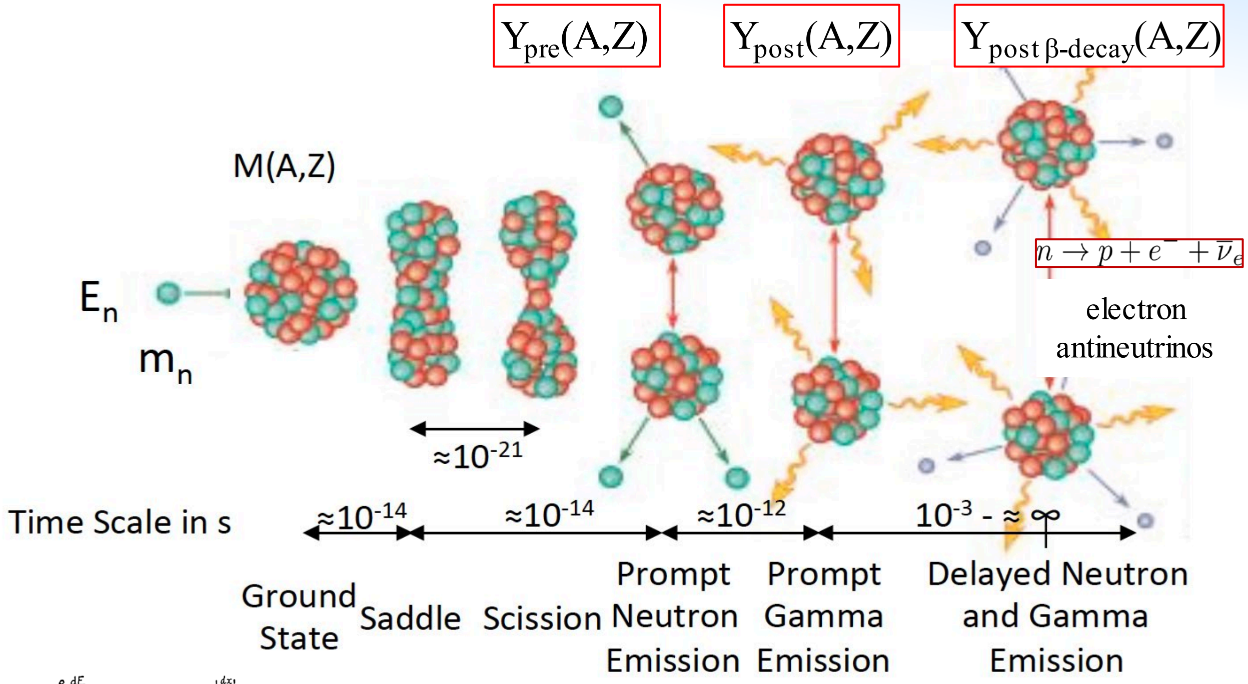
Slow: 10^{-16} sec

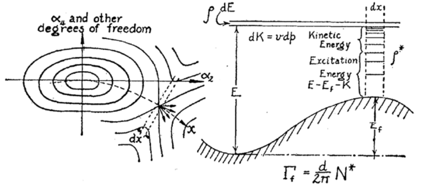
Analysis 1: Measurements
Analysis 2: Theory and computational simulation

Nuclear Fission



The Fission Process



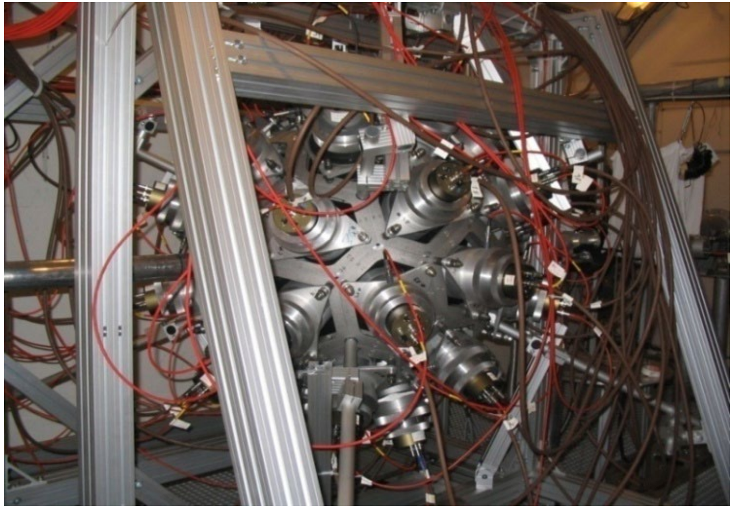


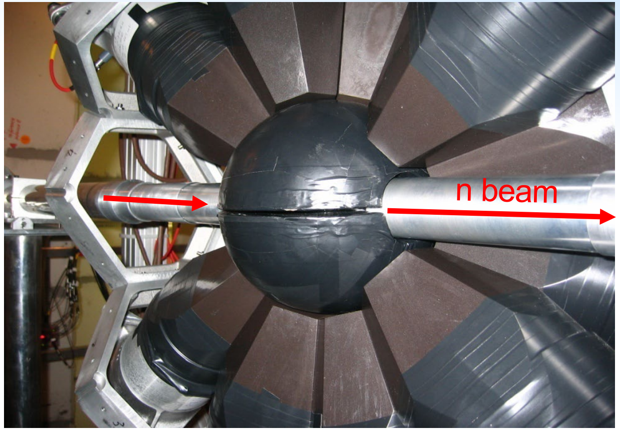
Pre-scission physics

IFY (**Independent Fission Yields**) → **CFY** (**Cumulative Fission Yields**)

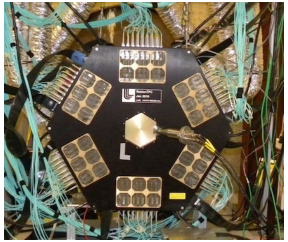
Nuclear reaction measurements

Total absorption detector at n_TOF (CERN)

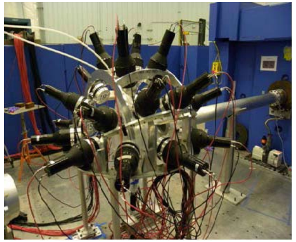




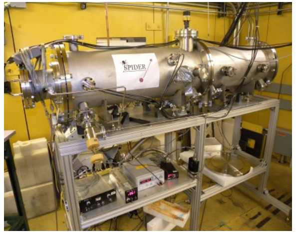
Fission Experiments at Los Alamos National Lab



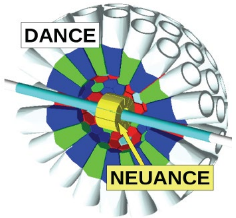
Time-Projection Chamber
for fission cross-section measurements



Chi-Nu setup
(22 6Li glass detectors) to measure prompt fission neutron spectra



SPIDER 2E-2v
for fission fragment yield measurements

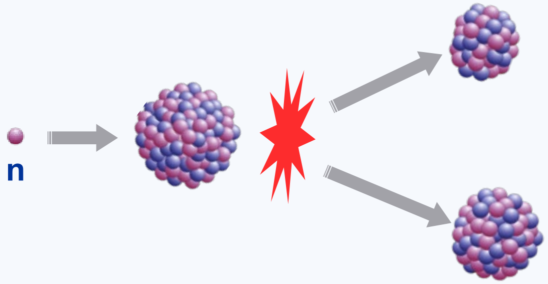


DANCE w/ NEUANCE
for correlated measurements on prompt fission neutrons and γ rays with fission fragments

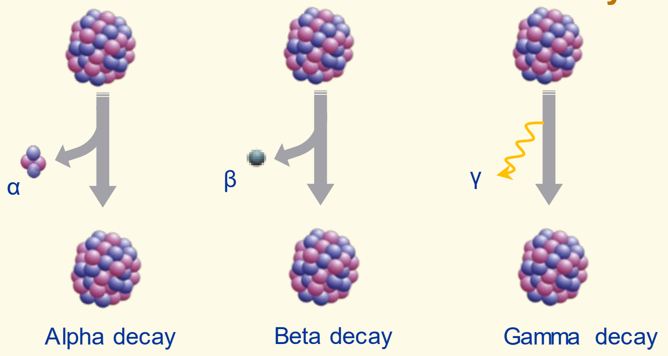
Many other facilities and detector setups in construction worldwide:

- EAR2 at CERN
- NFS @ SPIRAL2 @ GANIL
- IGISOL-JYFLTRAP
- SOFIA: Studies On Fission with Aladin (reverse kinematics) at GSI
- STEFF
- …

Nuclear Reaction



Nuclear Structure and Radioactive Decay



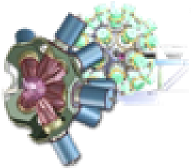
- Nuclear power
- Homeland security
- Nuclear fusion
- Medical applications (therapy and isotopes)
- etc.

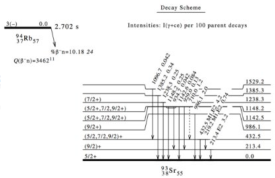
- Spent fuel and radioactive waste management
- Radiography, Nondestructive assay
- Safeguards
- Etc.

Nuclear Data

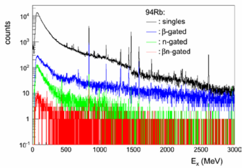
Make high-quality data available in numerical databases

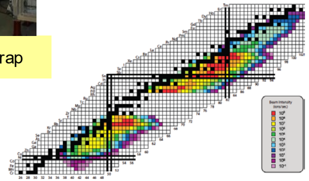
Nuclear physics research: experiment + theory

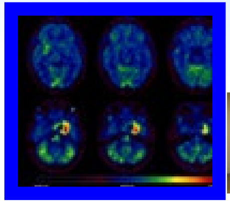




JYFLTRAP Penning trap



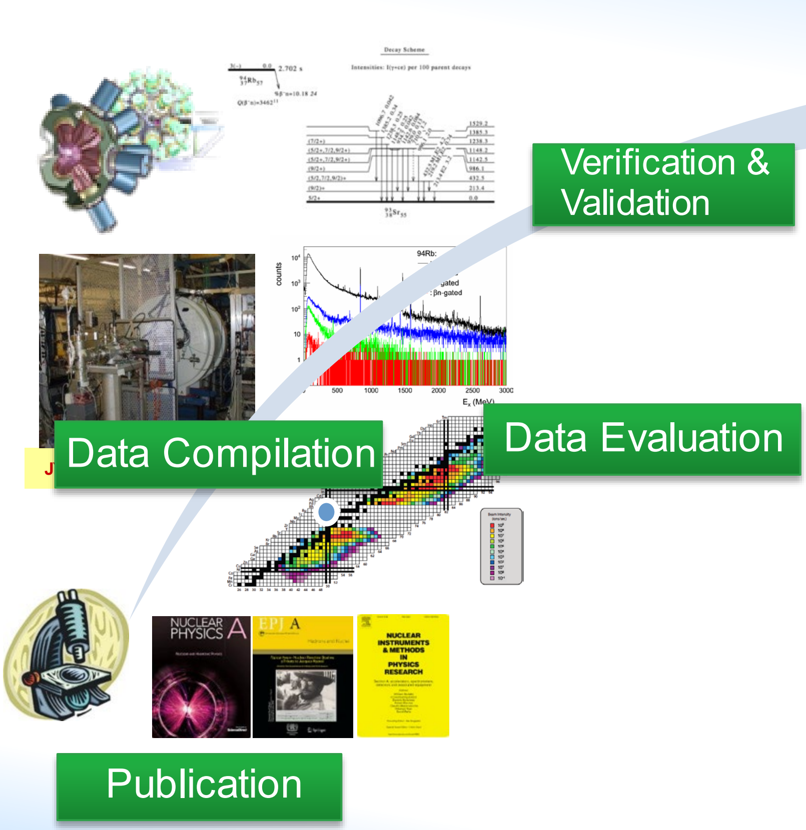




Applications:

organised
complete
recommended
traceable
easily retrievable

Nuclear data



Applications:

organised
complete
recommended
traceable
easily retrievable

IAEA Nuclear Data Section

IAEA

The Nuclear Data Section (NDS) supports nuclear research activities in Member States by providing essential nuclear data and serving as the IAEA centre for the collection and dissemination of data from laboratories worldwide.

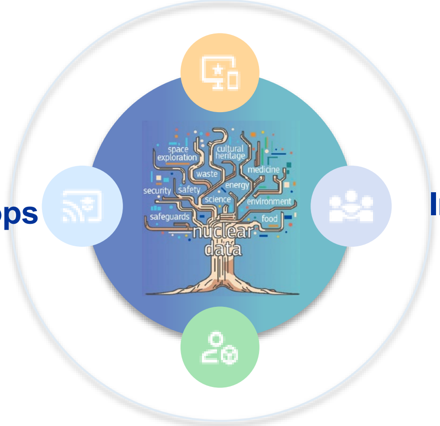
Web Service Developments
- Live Chart of Nuclide
- EXFOR, ENDF, CINDA, IBANDL, TALYSworld

Data Dissemination
- RIPL-3, CONDERC, Stopping Power,…
- IRDFF, Photonuclear, FENDL,…

Nuclear Data Dissemination

NSDD (Nuclear Structure and Decay Data Evaluators)
NRDC (Nuclear Reaction Data Centers)
INDEN (International Nuclear Data Evaluation Network)

Training & Workshops



International Network Coordination

Joint ICTP-IAEA Workshops
- Simulation of Nuclear Reaction Data with the TALYS Code
- Nuclear Structure and Decay Data
- AI for Nuclear, Plasma and Fusion Science

Nuclear Data Development

CRP (Coordinated Research Project)
DDP (Data Development Project)
Consultant Meetings and Technical Meetings

Some of our Databases and Web Applications

Nuclear Structure and Radioactive Decay

Nuclear Reactions

Nuclear Science and energy applications

Nuclear energy

Medical

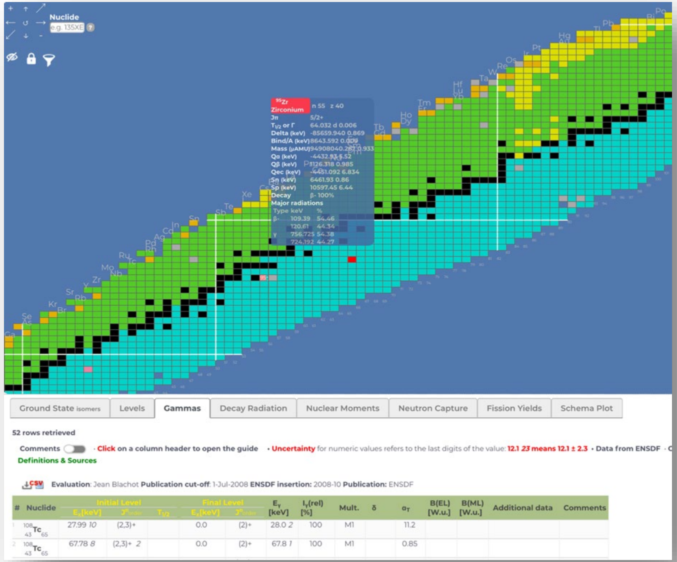
Safeguards

Application	URL	Contents
Live Chart of Nuclides/Isotope browser Mobile App	https://nds.iaea.org/relnsd/vcharthtml	Nuclear structure and decay data, user-friendly graphical interface, Python API, mobile apps
Decay Portal	https://nds.iaea.org/relnsd/vcharthtml/decay_libs.html	Decay Data Library Comparison
Atomic Mass Data, AME & Nubase	https://nds.iaea.org/amdc	Nuclear properties: mass, isomeric excitation energy, half-life, spin, parity, decay modes and intensities
Electronic Stopping Power of Matter for Ions	https://nds.iaea.org/stopping	Collection of stopping power measurements
Nuclear Electromagnetic Moments Database	https://nds.iaea.org/nuclearmoments	experimental information on nuclear magnetic dipole and electric quadrupole moments
Neutron Standards	https://nds.iaea.org/standards	The neutron cross section standards
EXFOR	http://nds.iaea.org/exfor	Experimental nuclear reaction database
Nuclear Reaction Data Explorer	https://nds.iaea.org/dataexplorer	Experimental and evaluated cross section and fission yield viewer
TALYS World	https://nds.iaea.org/relnsd/talys/talys.html	Nuclear reaction simulation online
Prompt Gamma-ray Neutron Activation Analysis	https://nds.iaea.org/pgaa	Prompt Gamma-ray Neutron Activation Analysis (PGAA) database and evaluated Gamma-ray Activation File (EGAF) for non-destructive nuclear method
Beta-Delayed Neutron Emission Database	https://nds.iaea.org/beta-delayed-neutron	Experimental beta-decay half-lives, beta-delayed neutron emission probabilities, and emission spectra
Compilation of Nuclear Data Experiments for Radiation Characterisation (CoNDERC)	https://nds.iaea.org/conderc/	Decay Heat, incident particle spectra used world wide, origen Input for shielding calculation, thermal resonane data
Medical Radioisotopes Production Portal	http://nds.iaea.org/medportal	Therapeutic Radionuclides, Gamma Emitters, Positron Emitters
Medical Isotope Browser	http://nds.iaea.org/mib	Medical radioisotopes production simulator
International Database of Reference Gamma Spectra (IDB)	https://nds.iaea.org/idb	In collaboration with IAEA-SG
IAEA Handbook of Nuclear Data for Safeguards	https://nds.iaea.org/sgnucdat	A set of recommended nuclear data for safeguard (decay data, thermal neutron capture cross section, resonance integrals, fission product yield ..etc)

Various codes are available on https://github.com/IAEA-NDS

Live Chart of Nuclides

- Nuclear structure and decay data (ENSDF) viewer
  - Available online and mobile app
  - Levels, decay radiation scheme, schema plot, gamma lines and energies, fission yields



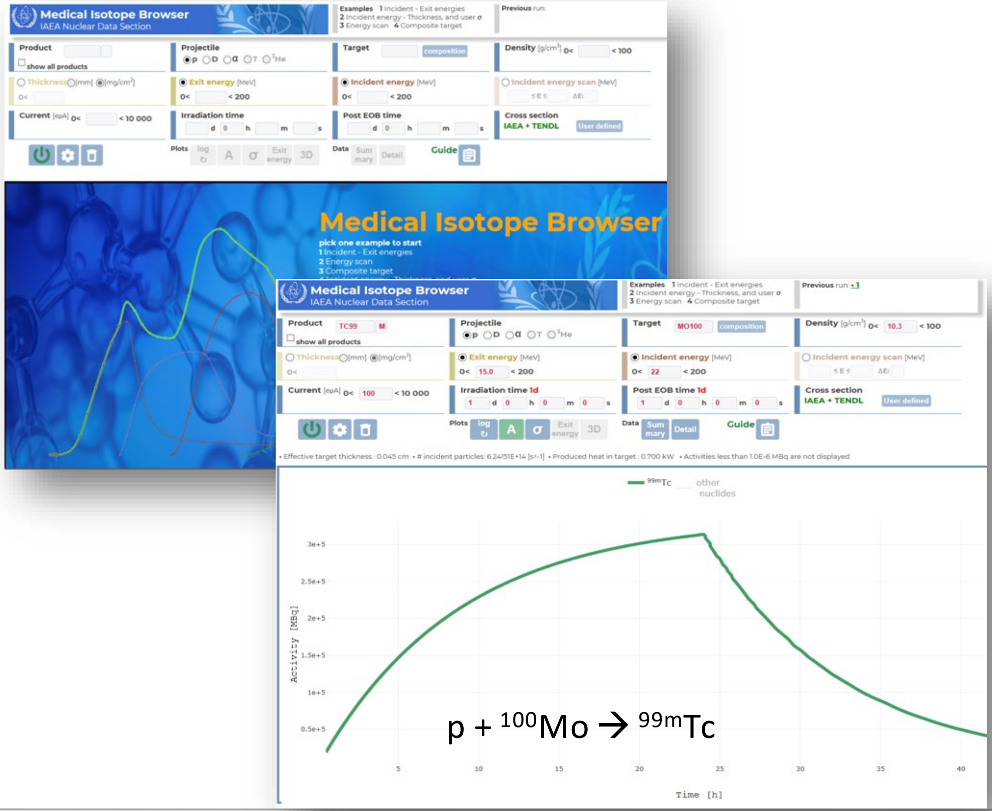
Livechart API + Data Science packages now also available

Isotope Browser – for Mobile Devices

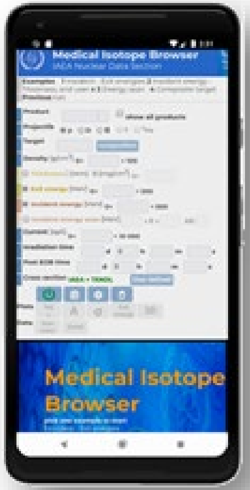
- App for Mobile Devices
  - Properties of over **4,000 isotopes**
  - **No internet** connection needed
  - **~180,000** downloads, **4.8**

WebApp: Medical isotope browser

- Medical isotope production simulator
  - Run the simulation online (accessible from any browser)
  - Setup target, projectile, the intensity and duration of irradiation, cooling time



$p + {}^{100}Mo \rightarrow {}^{99m}Tc$



Neutrons (reactors) and photons to be done

IAEA
International Atomic Energy Agency

Thanks for your attention!

physics@iaea.org