AMAZING FISSION

European Commission

Some nuclei are **unstable**: which means that they might **decay**. When it happens they emit radiation and **transmute** to (become) another nucleus.

Infographic about fission experiments
04/2021, C.L. Fontana (JRC-Geel)

This is a nucleus in an unstable equilbrium

Fission is the process in which very **heavy nuclei** break into two chunks, emitting also other smaller particles. It might be **spontaneous** or **induced** by a colliding neutron.

These are prompt and delayed neutrons that were produced in the fission. They might carry a lot of kinetic energy.

E_k

E_k

This is a delayed neutron

Neutrons that are produced can induce fission on other nuclei in a **chain reaction**.

This is a scared nucleus of uranium-235 (^{235}U) that will soon undergo fission, due to the neutron that will hit it.

These are light nuclei that can also be produced. They are normally gasses.

Gas accumulation in the material **embrittles** and damages it.

These are tiny voids filled with the gasses.

These are gamma rays produced during a fission event.

ENERGY!

Energy just for a sauna? No! For carbon-free electricity

Fission products and gamma rays release a lot of energy, that becomes **heat**.

Fission products are a resource of valuable radionuclides, e.g. for medicine, but they also constitute the long-lived portion of radioactive waste.

^{99m}Tc

These are fission products. They have roughly half the mass of the original nucleus.

$\frac{252}{2}$

This is a nucleus of Californium-252 (^{252}Cf) weighing itself.

This mass distribution describes the fission products yield.

252

This is the original mass of the nucleus

0 50 100 Mass [a.m.u.] 150 200 252

JRC-GEEL

Experience 40 YEARS

SPECIALIZED DETECTORS DEVELOPMENT

- Initiating instrument development.
- Key data for theory and modelling.
- Fission process comprehension.
- Enabling a priori assessments of nuclear safety and security.

This is our contribution to member states research institutions.

RESEARCH

Our role is to ignite research, that may culminate in **high impact publications**.

Article

Angular momentum generation in nuclear fission

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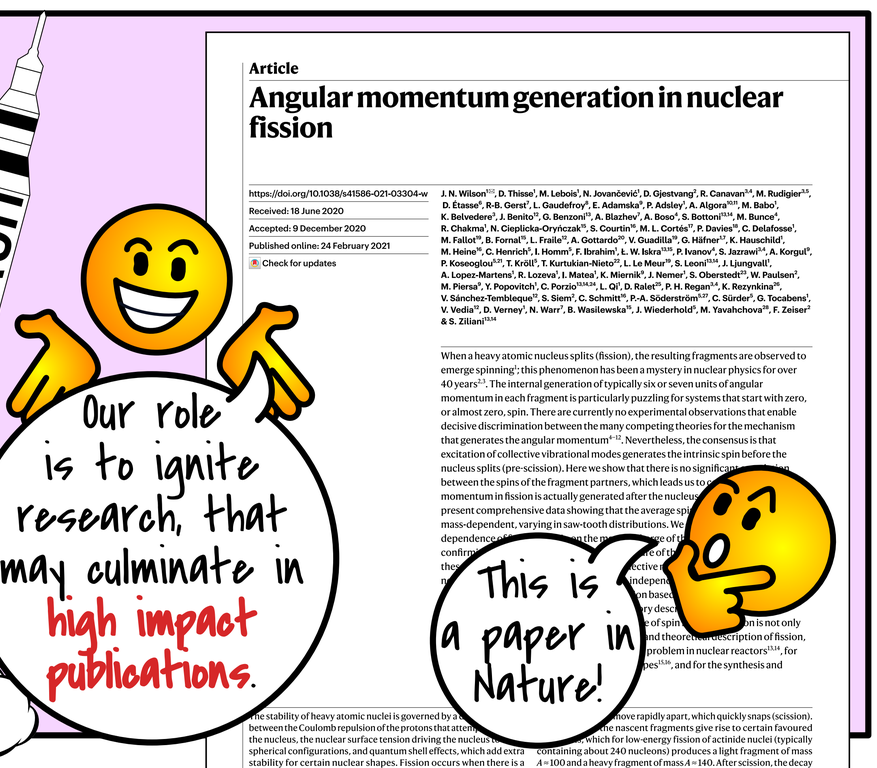
When a heavy atomic nucleus splits (fission), the resulting fragments are observed to emerge spinning[1]: this phenomenon has been a mystery in nuclear physics for over 40 years[2,3]. The internal generation of typically six or seven units of angular momentum in each fragment is particularly puzzling for systems that start with zero, or almost zero, spin. There are currently no experimental observations that enable decisive discrimination between the many competing theories for the mechanism that generates the angular momentum[4–12]. Nevertheless, the consensus is that excitation of collective vibrational modes generates the intrinsic spin before the nucleus splits (pre-scission). Here we show that there is no significant correlation between the spins of the fragment partners, which leads us to conclude that the momentum in fission is actually generated after the nucleus present comprehensive data showing that the average spi mass-dependent, varying in saw-tooth distributions. We dependence confirm the theo



Joint Research Centre

WONDERFUL METRO

European Commission

Good measurements and standards translate to better nuclear safety, security & safeguards: the so-called triple-S!

Safety
Security
Safeguards

A safe, secure and safeguarded nuclear energy helps to create a peaceful world and mitigate climate change.

What if we still used as reference the king's foot and he had swollen feet?

That plane might have the wrong amount of fuel for the distance!

Reliable measurements and standards are important for safety

The METRO team provides Certified nuclear Reference Materials, the CRMs.

CRM

triple-S

This is nuclear energy →

This is climate ↘

This is peace →

This is an abyss ↓

Nuclear safety depends on the knowledge of the physical processes.

These are the pillars on which experiments are built to improve our knowledge

TRIPLE-S

NUCLEAR DATA EXPERIMENTS

ACCELERATORS

The METRO team makes targets

TARGETS

DETECTORS

DATA ANALYSIS

Nuclear data is obtained by shooting particles to targets and detecting the byproducts.

This is a target →

This is a particle ↑

These are byproducts ↓

Targets → must be well characterized for high quality measurements

This is a law enforcement officer

Accurate data and knowledge allow effective detection, to avoid malicious uses of nuclear materials, safeguarding society

This is an alarm.

This is an angry mischief.

Nuclear forensics identifies the origin of nuclear materials by their fingerprints.

This is emitted radiation from the material.

This is an unknown isotopic material

Fingerprints, signatures and age are determined with Certified nuclear Reference Materials, the CRMs.

This is a mass spectrometer that measures the material isotopic signature.

The METRO team has the BELAC accreditations ISO17025, ISO17034, and ISO17043

This is the muse Calliope

Triple-S also needs standardized measurement procedures otherwise results might be unreliable.

We need more CRMs and standards!

This is an unstable situation ↙

These are non-standard materials and procedures ←

Infographic about the METRO team
09/2021, C.L. Fontana & Y. Aregbe (JRC-Geel)

triple-S

Preserving nuclear skills

Nuclear references and standards

Joint Research Centre

The JRC provides the references and standards on which we can build on in a rapidly changing world!

The METRO team contributes offering targets, standards, CRMs, and knowledge.

This is what triple-S needs →

Safety
Security
Safeguards

standards

data

knowledge

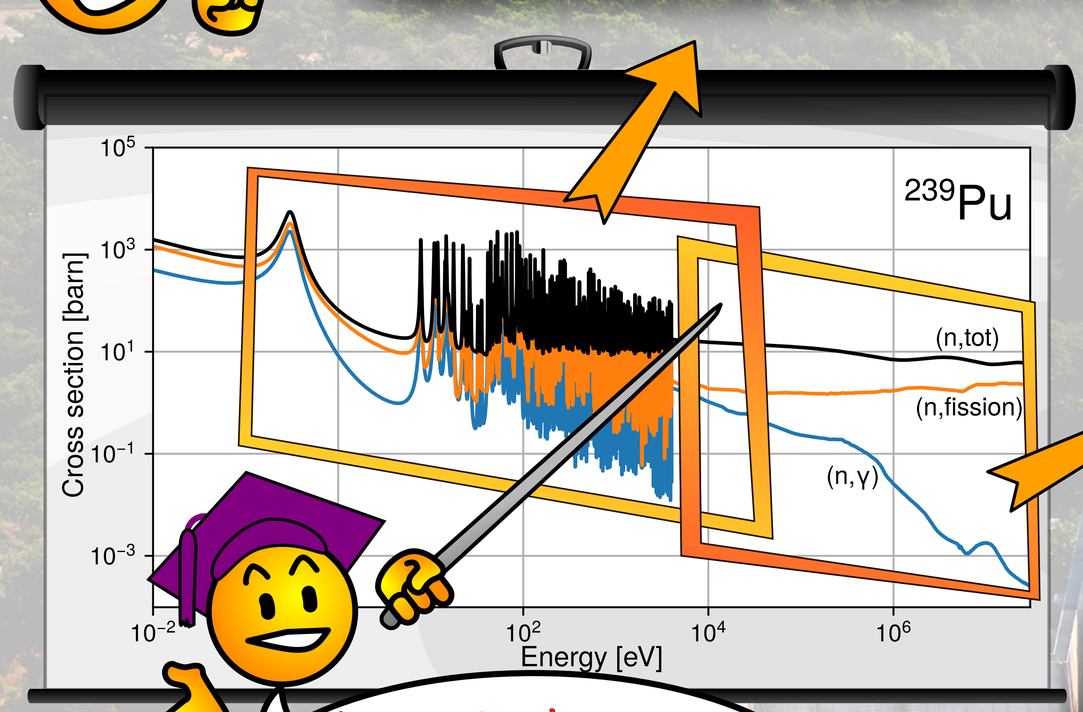
European Commission

MONNET
MONo-energetic Neutron Tower

MONNET and GELINA are complementary neutron sources, with a total energy domain of 9 orders of magnitude!

GELINA

MONNET



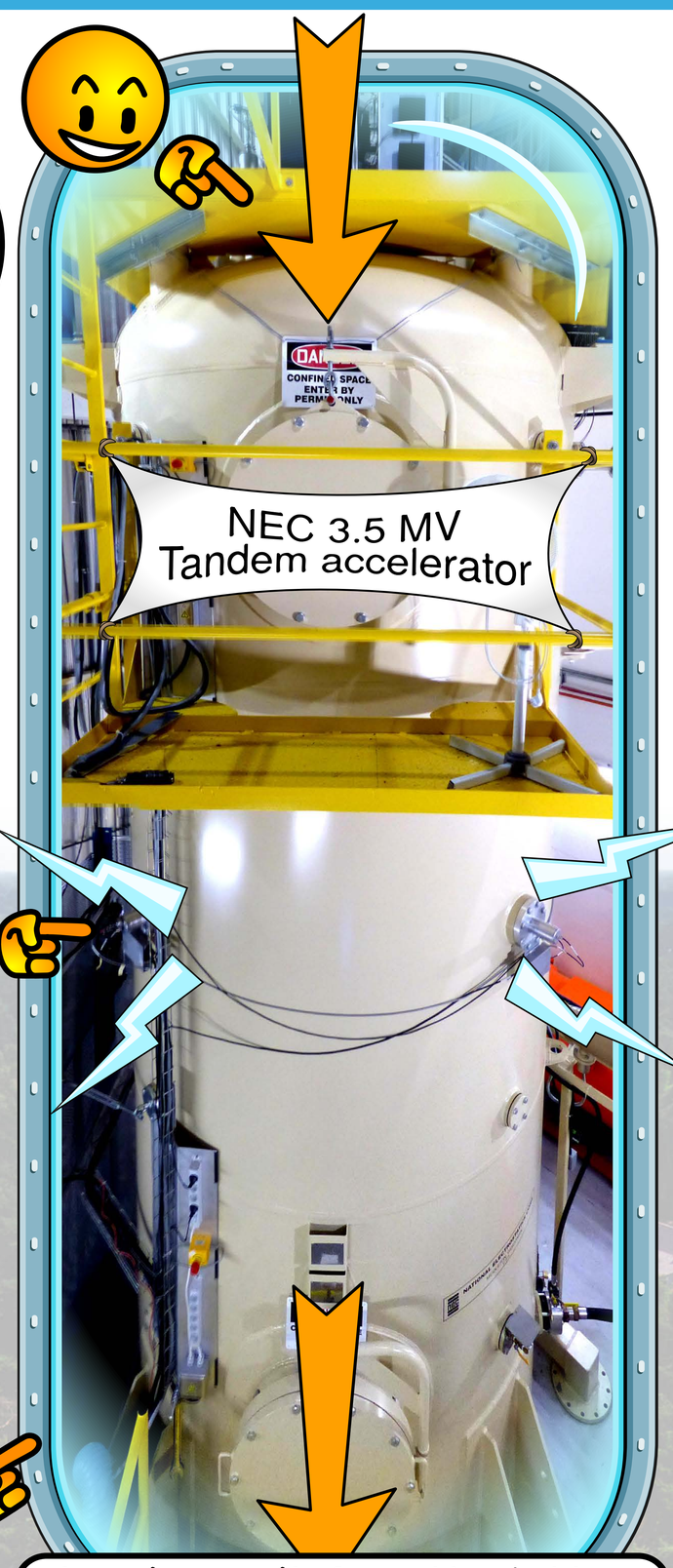
An overlapping energy range is a unique feature of JRC-Geel: it allows in-house data quality assurance.

The specialties are...

MONOENERGETIC NEUTRONS!!

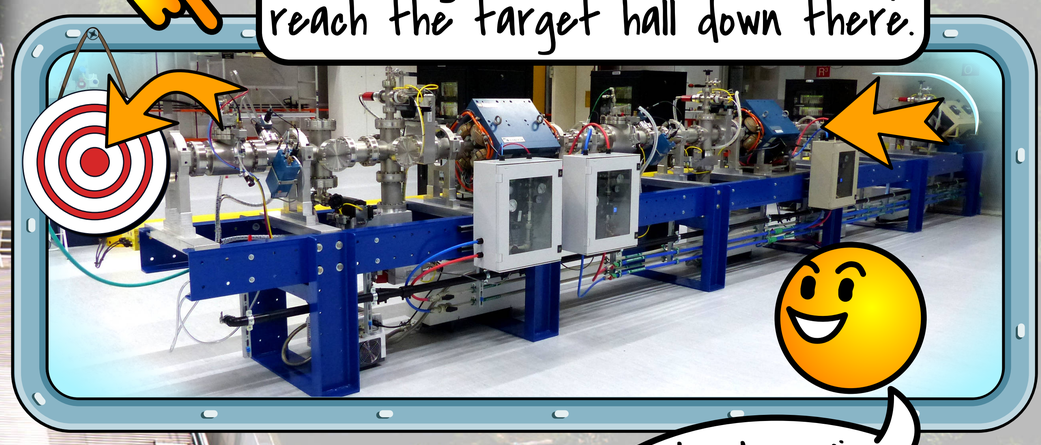
GAMMA BEAMS!!

Ions are accelerated in the tank, by a central terminal, with a voltage of 3.5 MV.



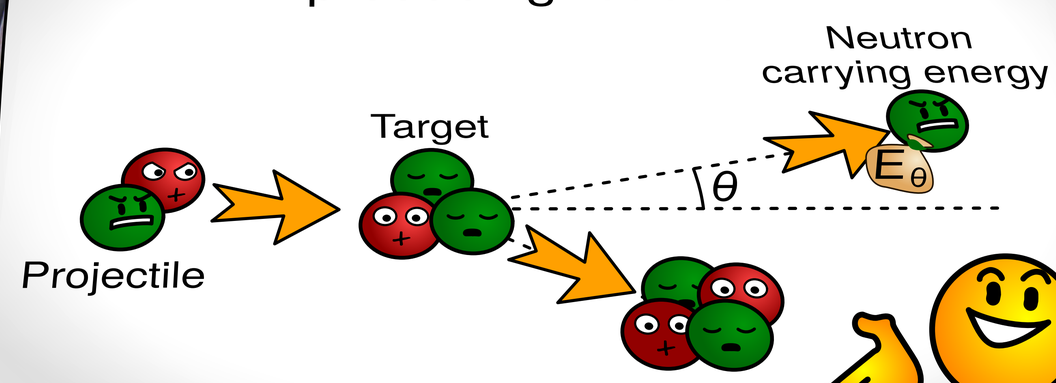
Ions enter from the top of the tank.

Then, ions exit from the bottom. Travelling in the beamlines, they reach the target hall down there.



The beamline guides and focuses the ion beam on the target at the end.

Example of a neutron producing reaction



Neutrons are produced with particular nuclear reactions in the target.

Joint Research Centre

Infographic about the MONNET accelerator
04/2021 C.L. Fontana (JRC-Geel)

SPECTACULAR NEUTRONS!

European Commission

Why are neutrons so important?

Infographic about neutrons applications
04/2021, C.L. Fontana (JRC-Geel)

This is a uranium nucleus

This is a moving neutron

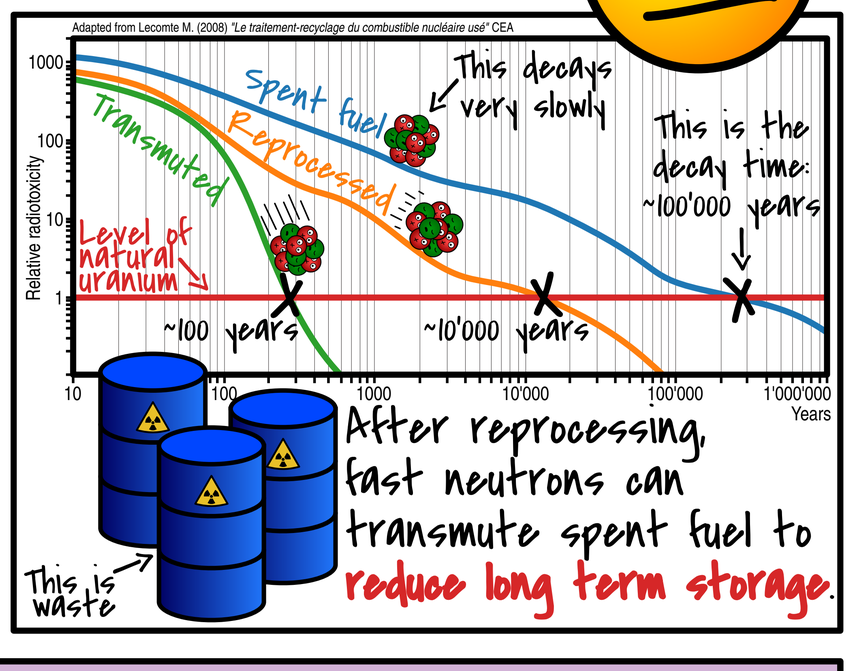
ENERGY!

More neutrons!

These are lighter nuclei

Carbon-free energy production

Nuclear reactor safety depends on the knowledge of neutron interactions.



After reprocessing, fast neutrons can transmute spent fuel to reduce long term storage.

It's like sculpting nuclei. Subtract or add a bit, but it has to be just right.

The incoming neutron steals another neutron!

This nucleus becomes a nucleus useful for doctors and patients.

This is the incoming neutron

This is a collaborative work that is taking off

JRC Petten

JRC Geel

Medical isotopes

Open Access

SCK CEN

Medical radionuclide production techniques

Neutrons induce radiation damage on structural materials and electronics.

Yes! It's dangerous

This is a moving proton that was hit

This is a damage

This is studying the damage

JRC-Petten

Materials testing

That is a hidden package containing illicit materials

These are fast neutrons that analyze the package

These are the gamma rays produced by the neutrons in the package

Materials emit charcteristic gamma rays: their fingerprints!

Detection of illicit materials

This is a sealed metallic statuette

Neutron radiography

These are neutrons that easily passed through the metal, that we can see.

Those are neutrons strongly interacting with the light material.

Light materials can be detected with neutrons, with X-rays is difficult.

This is light parchment hidden inside

...but wait! There's more! With these gamma rays we can detect tiny amounts of elements in objects.

This is the gamma detector that measures the elements' fingerprints

These neutrons can be fast or slow

Neutron Activation Analysis

I need nuclear reference data to simulate reactors and nuclear medicine procedures.

This is a computer simulation

This is a simulated nucleus

This is a simulated moving neutron

Nuclear reactions modelling

IAEA
Academia
NEA OECD
Member states
JRC

These are some stakeholders

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