Nuclear data

From measured quantities to reliable predictions

DATA

measure
evaluate
use
repeat

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What nuclear data include

A complete description of a nucleus and what it can do

Cross sections are one part - not the whole system

Identity and bulk properties

masses · separation energies · Q values · natural abundances

Nuclear structure

levels · spins and parities · lifetimes · transition probabilities

Decay

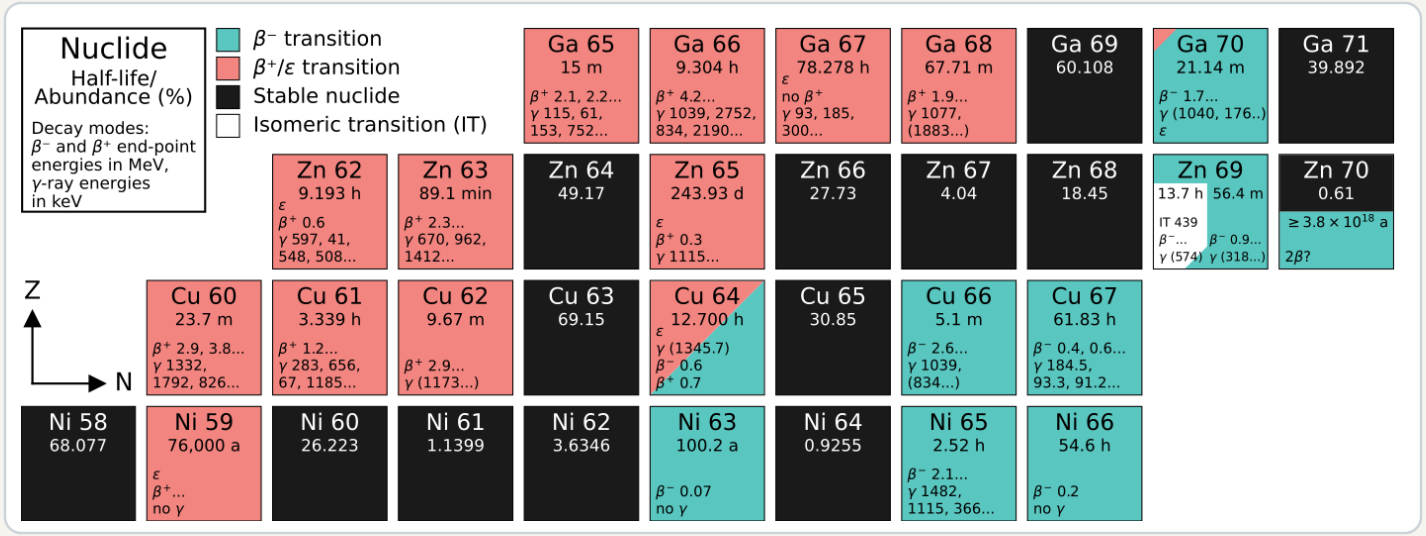
half-lives · branches · radiation energies and intensities · delayed particles

Reactions and emissions

cross sections · resonances · distributions · yields · covariances

ONE CELL

mass
half-life
decay modes
radiation energies



THEN ADD

reaction data
uncertainty
covariance
provenance

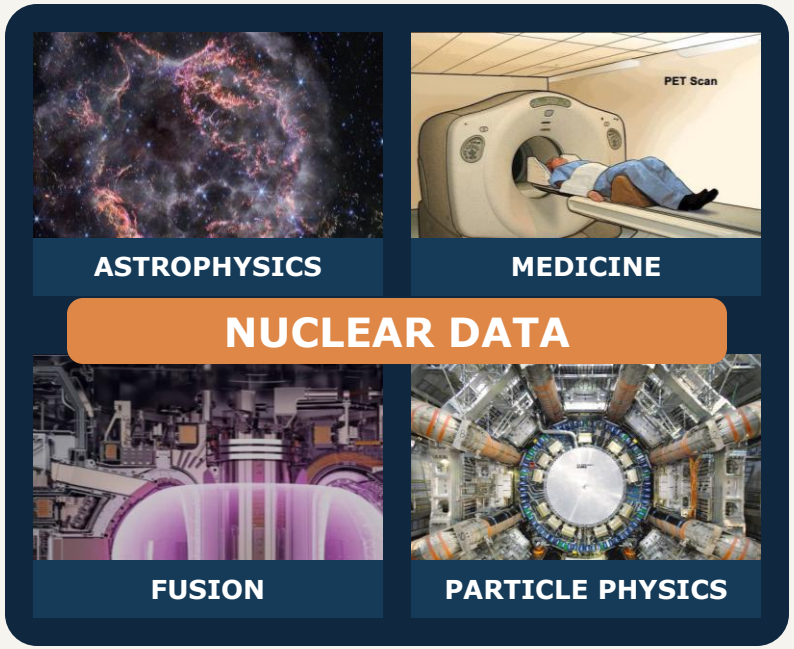
Applications that depend on nuclear data

Fundamental physics
structure, reactions, tests of models

Astrophysics
reaction rates and nucleosynthesis

Energy
criticality, burnup, decay heat, shielding

Medicine
isotope production, imaging and dose



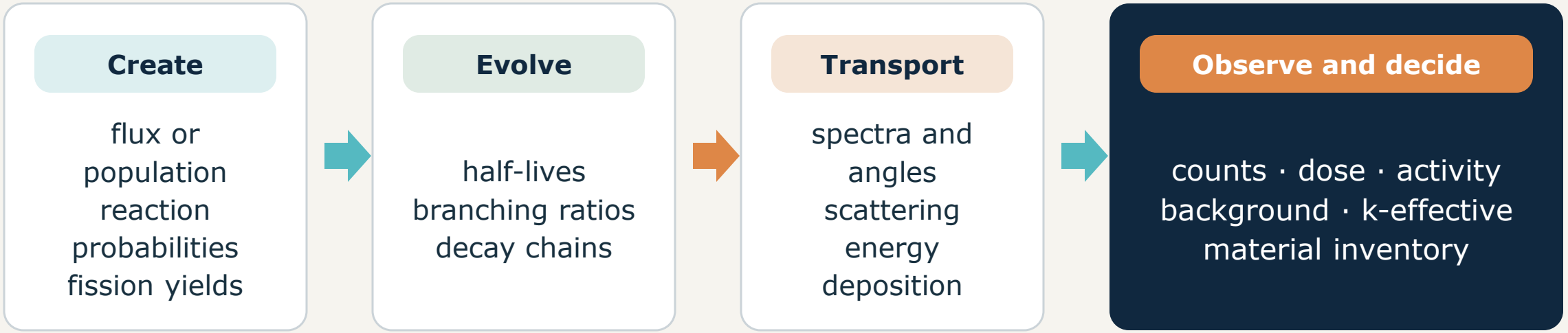
Particle and rare event physics
activation, backgrounds, detector response

Fusion and materials
damage, transmutation and inventories

Safeguards and security
signatures, assay and forensics

Space, industry and environment
dose, electronics, analysis and dating

From microscopic quantities to observables



$$R = N_t \int \Phi(E)\, \sigma(E)\, dE$$

$$dN_i/dt = \text{production} + \text{feeding} - \text{removal} - \text{decay}$$

Every final number combines several nuclear datasets, experimental inputs and correlations.

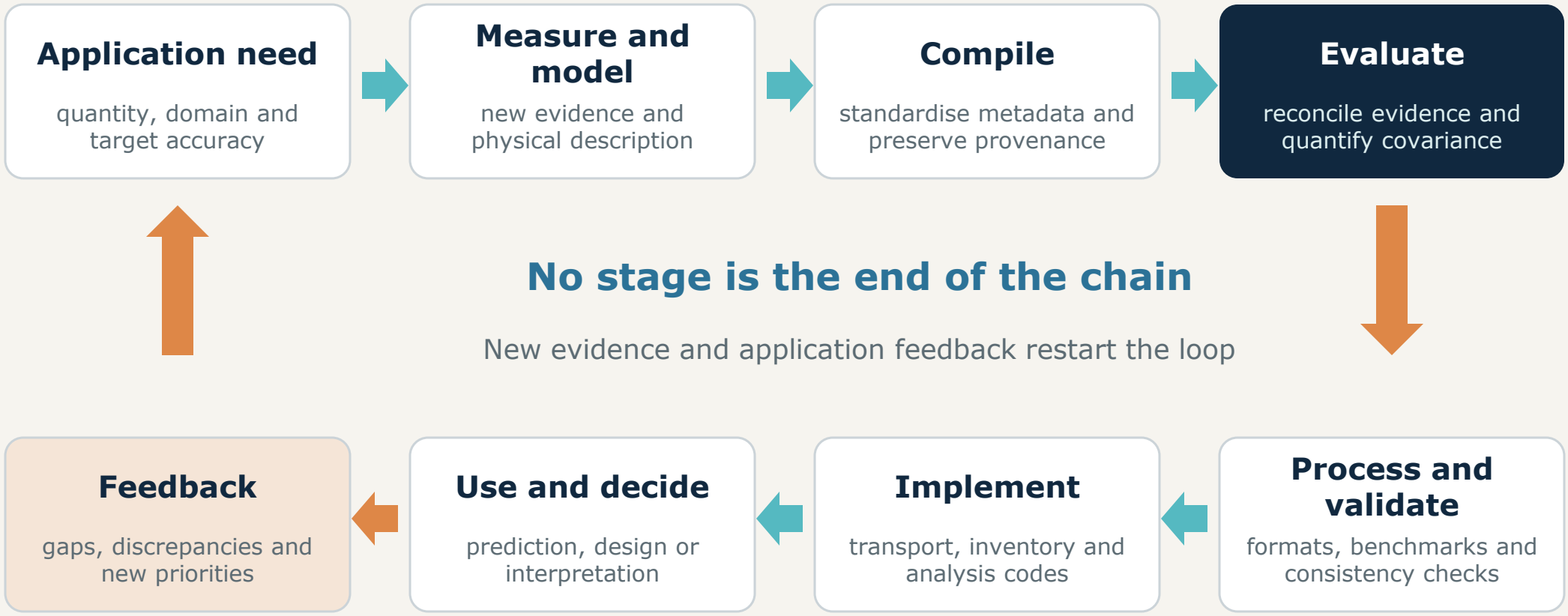
The nuclear data ecosystem

Different resources answer different questions

Role	What it contains	Examples
Literature and indexing	Published work organised by nuclide, reaction and subject	NSR · CINDA · INIS
Experimental records	Measured values, methods, uncertainties and metadata	EXFOR · XUNDL
Evaluated structure and decay	Recommended masses, levels, half-lives and decay radiations	ENSDF · AME/NUBASE · DDEP
Evaluated reactions	Self-consistent reaction files, spectra and covariances	ENDF/B · JEFF · JENDL · CENDL · BROND · TENDL
Models and parameters	Inputs for reaction calculations and interpolation	RIPL
Application and processed data	Collections or formats prepared for a task or transport code	FENDL · IRDFF · IBANDL · MIRD · medical portals · ACE · Geant4

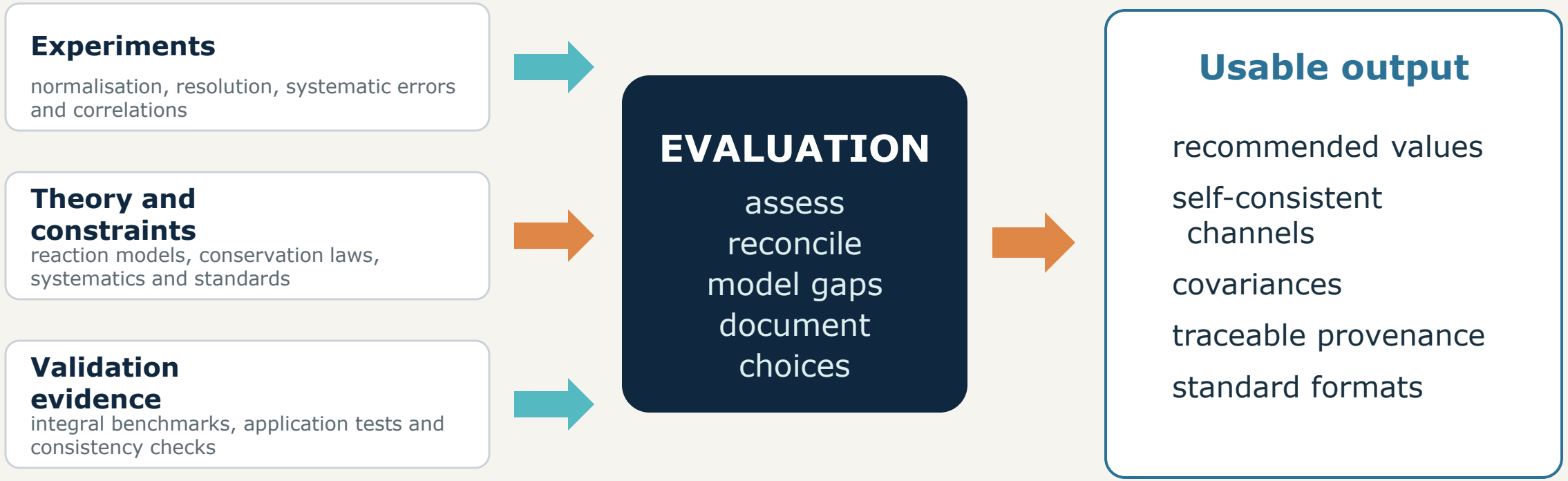
EXFOR: experimental reaction records. ENDF/B, JEFF, JENDL and peers: evaluated reaction files.

The nuclear data feedback loop



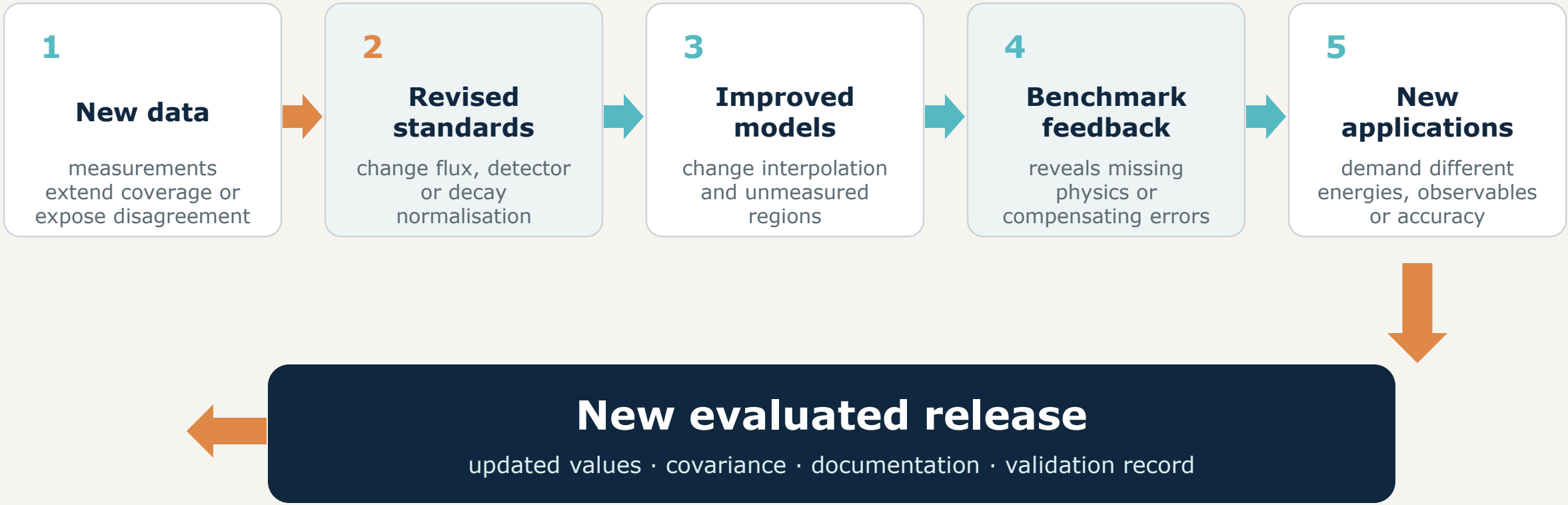
What evaluation contributes

Evidence is usually incomplete, inconsistent and unevenly precise



Averaging points rarely produces a good evaluation.

Why evaluations need revision



Each release reflects the evidence and application needs available at that time.

Why new measurements remain essential

Models connect measured regions. Experiments anchor the connection.

01	**Coverage gaps**	important nuclides, energy ranges and reaction channels still lack data
02	**Accuracy limits**	existing uncertainties dominate a dose, yield, background or safety margin
03	**Missing observables**	spectra, angles, isomeric ratios, fission yields and delayed emissions remain incomplete
04	**Legacy limitations**	older work may lack raw data, metadata, systematic correlations or modern standards
05	**Changing use cases**	fusion, advanced reactors, isotope production and rare event searches probe new domains



n_TOF experimental area · CERN

A new measurement is more than a new point

observables · metadata · systematics · covariance

A mature database can still contain decisive gaps for a new application.

Current challenges in nuclear data

Scientific challenges

- coverage across nuclides, particles, energies and observables
- disagreement, shared normalisations and hidden correlations
- model bias when extrapolating beyond measured regions
- complete covariance and coupled decay or reaction networks

Infrastructure challenges

- limited evaluator time and a specialised workforce
- traceable metadata, raw data preservation and reproducibility
- synchronised releases across databases, portals and codes
- validation benchmarks and fast feedback from users

Continuity of expertise and update pathways is now a major bottleneck.

Application driven priorities

The useful question is where improved data change a decision

1. **Define the output** — dose · k-effective · yield · inventory · background
2. **Propagate uncertainty** — identify the nuclides, reactions and decay quantities that dominate
3. **Set a target accuracy** — specify energy range, observable and acceptable uncertainty
4. **Coordinate the response** — measurement · theory · evaluation · benchmark



NEA High Priority Request List

FORMAL PRIORITISATION

turn an application need into a coordinated measurement and evaluation response

Also: IAEA coordinated research projects · application specific issue lists

Case study · Cu-64 and Cu-67

One element, complementary decay modes - and a compact test of the full data chain

^{64}Cu — PET imaging

$t_{1/2}$ = 12.70 h · β^+ / EC decay

^{64}Ni(p,n)^{64}Cu benchmark route

↔ same chemistry

^{67}Cu — β^- therapy

$t_{1/2}$ = 61.83 h · β^- decay

^{70}Zn(p,α)^{67}Cu and ^{nat}Zn(p,x)^{67}Cu

What the experiment had to determine

Production

excitation functions across a wide energy

Separation

^{67}Cu from ^{67}Ga in shared γ lines

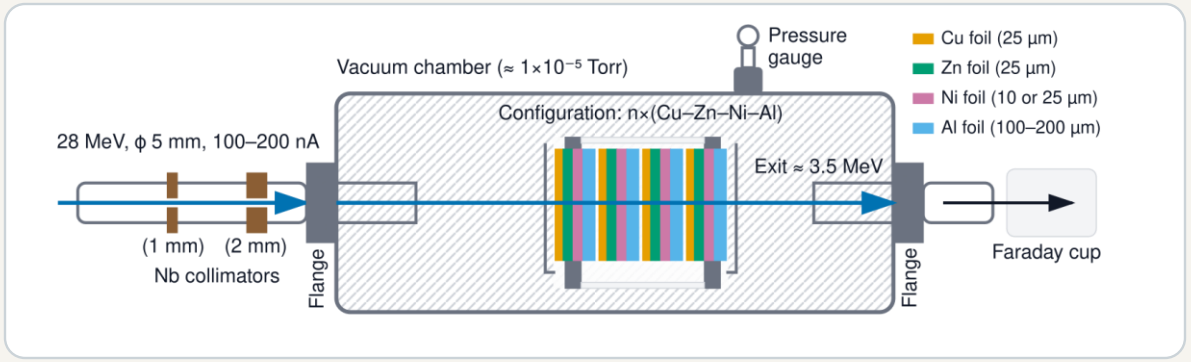
Interpretation

natural target data into isotope channels

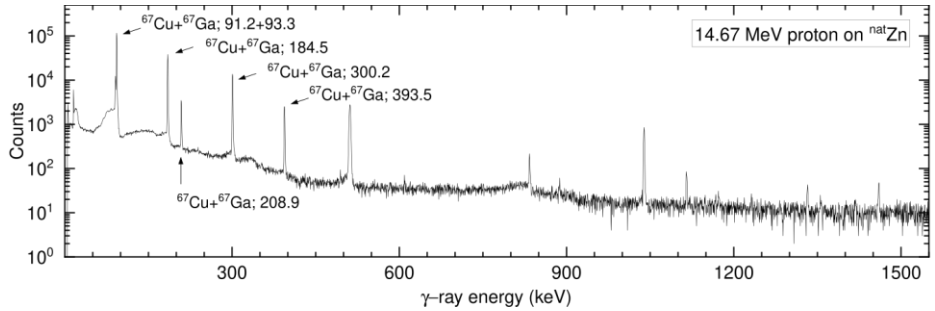
Time-resolved γ-ray spectrometry ultimately enabled seven excitation functions.

One irradiation, several layers of inference

Stacked foils map energy in one irradiation



Shared γ lines require time information



1 · Beam + target

Cu/Ni monitor reactions, foil areal density and energy degradation set E and fluence.

2 · Repeated HPGe

Typically 8–10 spectra per Zn foil, extending to about two weeks after EOB.

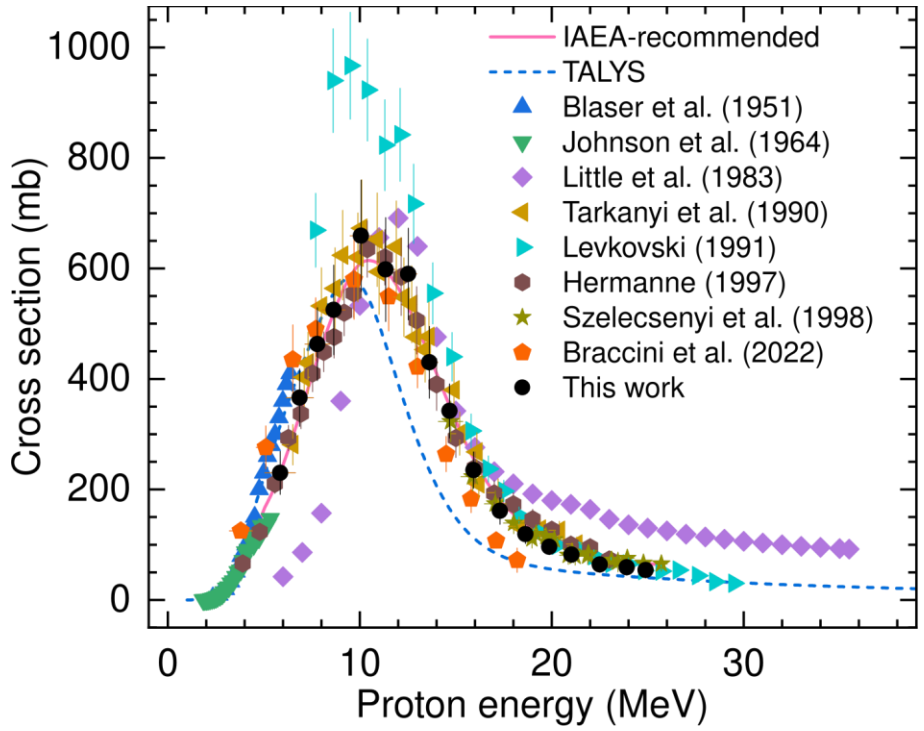
3 · Joint deconvolution

Shared lines and different half-lives separate ^{67}Cu (61.83 h) from ^{67}Ga (78.28 h).

Counts become cross sections only after reaction and decay data are combined.

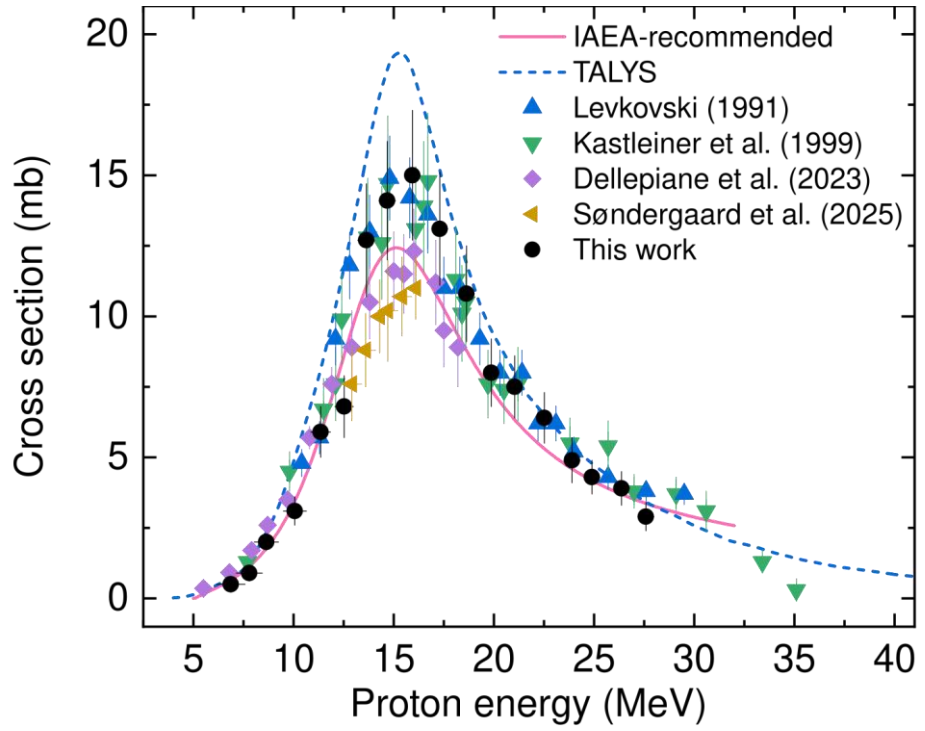
Two excitation functions (different lessons)

^{64}Ni(p,n)^{64}Cu · benchmark route



3.8–18.3 MeV · within the established spread
Practical production window ≈ 6–14 MeV

^{70}Zn(p,α)^{67}Cu · extraction challenge



Peak ≈15 mb at 15 MeV · window ≈11–22 MeV
Model gets the shape but overpredicts the peak

Cu-67: not one peak, not one channel

1 · Spectral mixture

^{67}Cu and ^{67}Ga share several γ-ray energies. Cooling time dependence supplies the missing information.

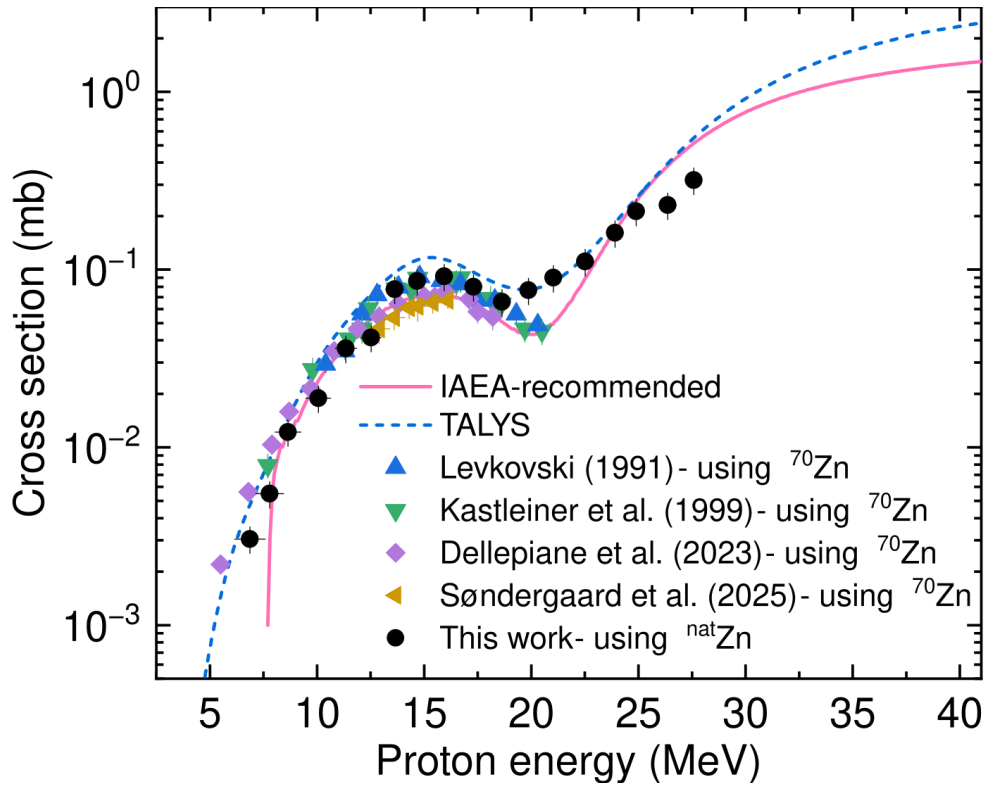
2 · Reaction mixture

^{nat}Zn(p,x)^{67}Cu combines ^{70}Zn(p,α) at lower energy with ^{68}Zn(p,2p) above ≈20 MeV.

3 · Evaluation lesson

Evaluated curves guide decomposition and comparison; new measurements expose where model normalisation needs work.

Composite ^{nat}Zn(p,x)^{67}Cu excitation function



New data to 28 MeV capture the high-energy rise and feed the next evaluation cycle.

Messages

01 — Nuclear data cover properties, structure, decay, reactions, emissions and their uncertainties.

02 — Their value comes from a maintained chain of measurement, compilation, evaluation, validation and use.

03 — New data and repeated evaluation remain necessary because evidence, standards and applications change.

A reliable prediction requires traceable data.