Nuclear Data and its relation to QCD

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U.S. DEPARTMENT OF ENERGY

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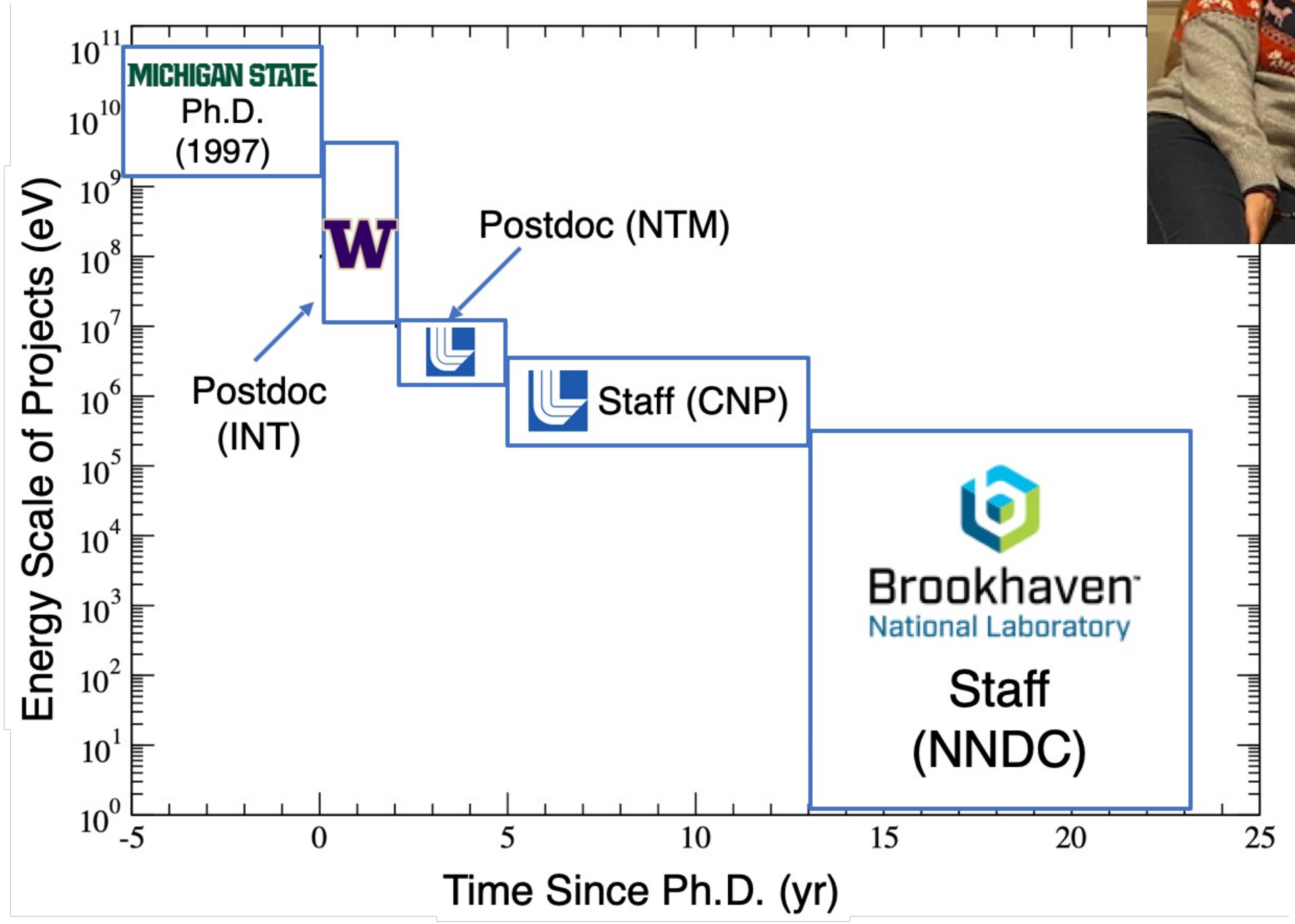
Apparently I am an unofficial ambassador



Responsibilities

- Head of the NNDC
- Chair USNDP & CSEWG
- Outgoing ENDF Library manager; coordinated ENDF/B-VII.1 & ENDF/B-VIII.0 library releases
- PI for number of NNSA and DOE-NP projects
- Outgoing chair of Expert Group on GNDS

Why are we even talking about nuclear data at this townhall?

- Because we have to:
  - NSAC Nuclear Data charge
  - Nuclear data is a cross cut for all town halls

- But really, I hope to argue that it is in our (collective) best interests

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U.S. Department of Energy
and the
National Science Foundation

April 13, 2022

Professor Gail Dodge
Chair, DOE/NSF Nuclear Science Advisory Committee
College of Sciences
Old Dominion University
4600 Elkhorn Avenue
Norfolk, Virginia 23529

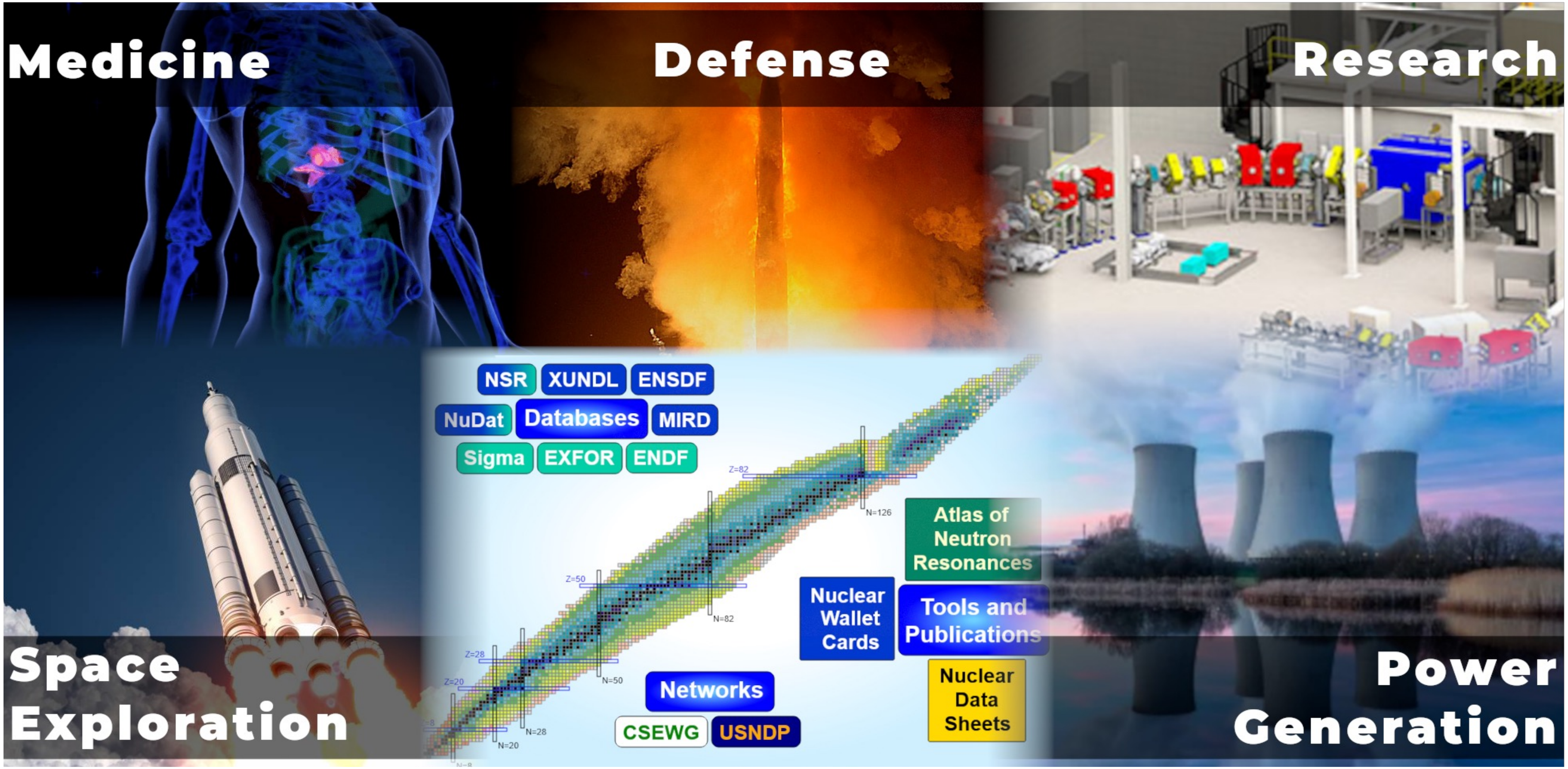
Dear Professor Dodge:

This letter is to request that the Nuclear Science Advisory Committee (NSAC) establish an NSAC Sub-Committee to assess challenges, opportunities, and priorities for effective stewardship of nuclear data.

"Nuclear data" is data derived from observed properties of nuclei, their decays and decay products, and the interactions of both nuclei and their decay products with other nuclei, subatomic particles or in bulk matter. Data from theoretical models created for comparison with experimental nuclear data may also be considered for inclusion under this definition.

Increasingly, access to accurate, reliable nuclear data plays an essential role in the success of Federal missions such as non-proliferation, nuclear forensics, homeland security, national defense, space exploration, clean energy generation, and scientific research. Data access is also key to innovative commercial developments such as new medicines, automated industrial controls, energy exploration, energy security, nuclear reactor design, and isotope production. The mission of the United States Nuclear Data Program (USNDP) managed by the Department of Energy (DOE) Office of Science Nuclear Physics (NP) program is to provide current, accurate, authoritative data for workers in pure and applied areas of nuclear science and engineering. This is accomplished primarily through the compilation, evaluation, dissemination, and archiving of extensive nuclear datasets. USNDP also addresses gaps in nuclear data, through targeted experimental studies and the use of theoretical models. A keystone of USNDP stewardship of nuclear data is the activity of the National Nuclear Data Center (NNDC) hosted at Brookhaven National Laboratory.

Who we are and what we do … in one slide



www.nndc.bnl.gov

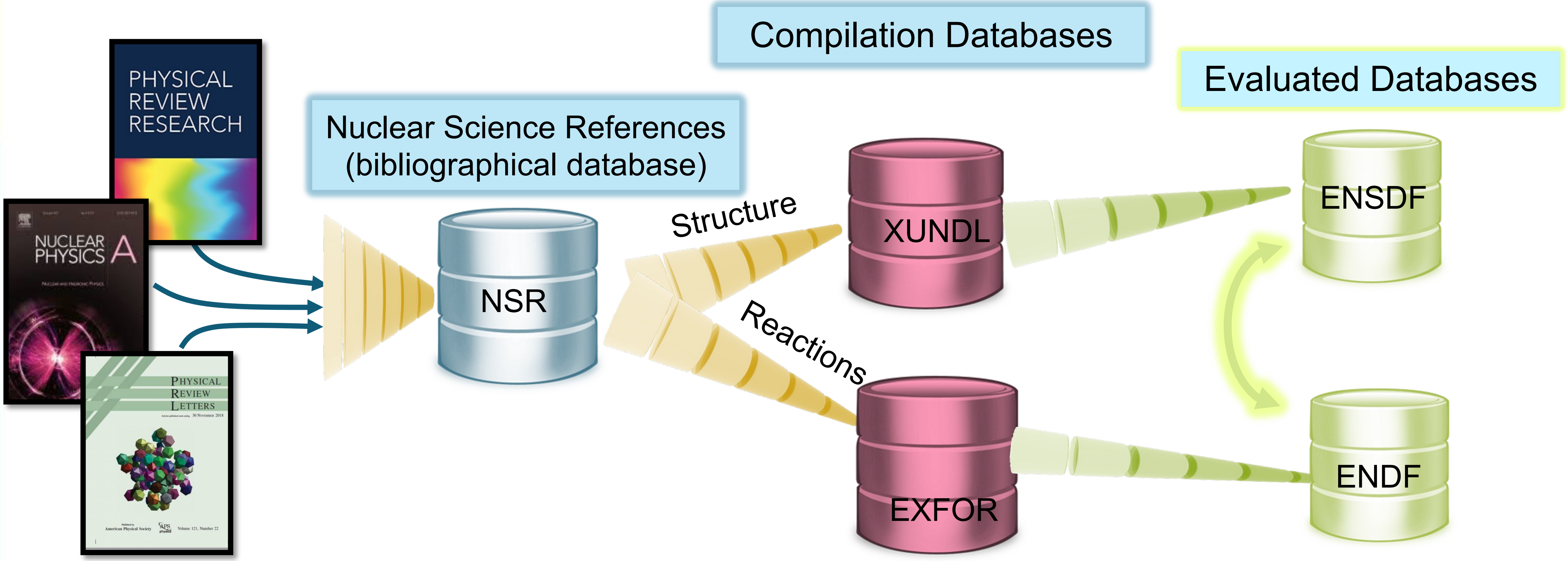
NNDC Vision & Mission

The National Nuclear Data Center (NNDC) vision is to be the premier global resource for nuclear data and plan to:

- ❑ Implement AI/ML algorithms to reduce the time from data publication to integration in a recommended library to less than two years.
- ❑ Establish an open data repository for low-energy nuclear physics.
- ❑ Advance dissemination efforts with modern and efficient software tools.
- ❑ Sustain a robust nuclear physics research portfolio, including the development of an experimental program to accelerate isotope production science.

The NNDC is the lead and largest unit of the U.S. Nuclear Data Program (USNDP), whose mission is to provide current, accurate, authoritative data for workers in pure and applied areas of nuclear science and engineering. This is accomplished primarily through the compilation, evaluation, dissemination, and archiving of extensive nuclear datasets. USNDP also addresses gaps in the data, through targeted experimental studies and the use of theoretical models.

How we do it



- Publications are 95% source of data
  - Journals
  - Lab Reports
  - Theses
- Literature scanned on weekly basis

- Extract meta- and numerical data
- Data converted to database format
- Several consistency checks of data

- Critical assessment of all exp data
- Provide recommended values
- Testing and Validation important component

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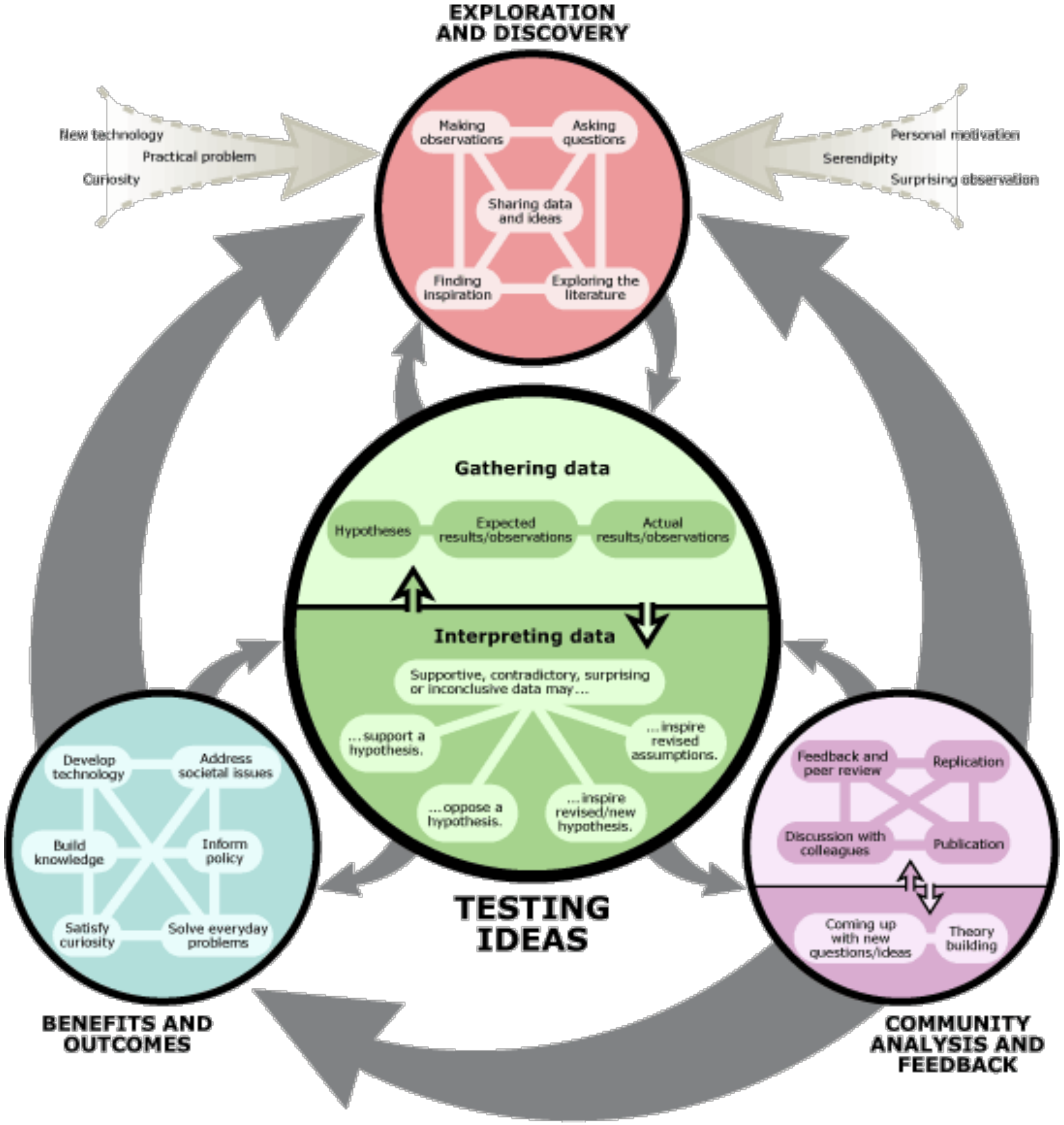
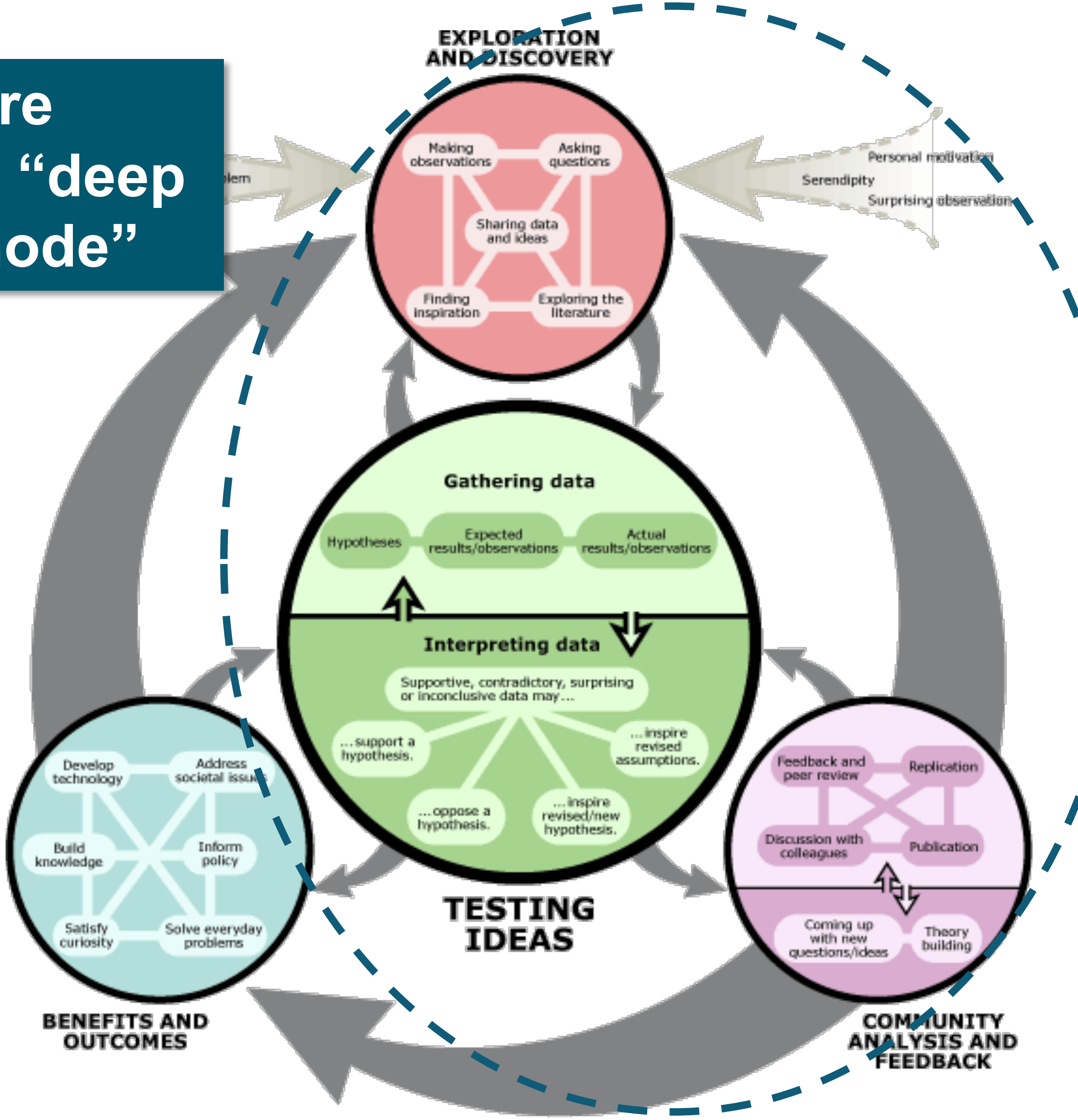
S.M. Arlidge, A. Thanukos, J.R. Bean, “Using the Understanding Science Flowchart to Illustrate and Bring Students’ Science Stories to Life”, *The Bulletin of the Ecological Society of America*, pp. 211-226 (2017)



We focus here when we are "deep in science mode"



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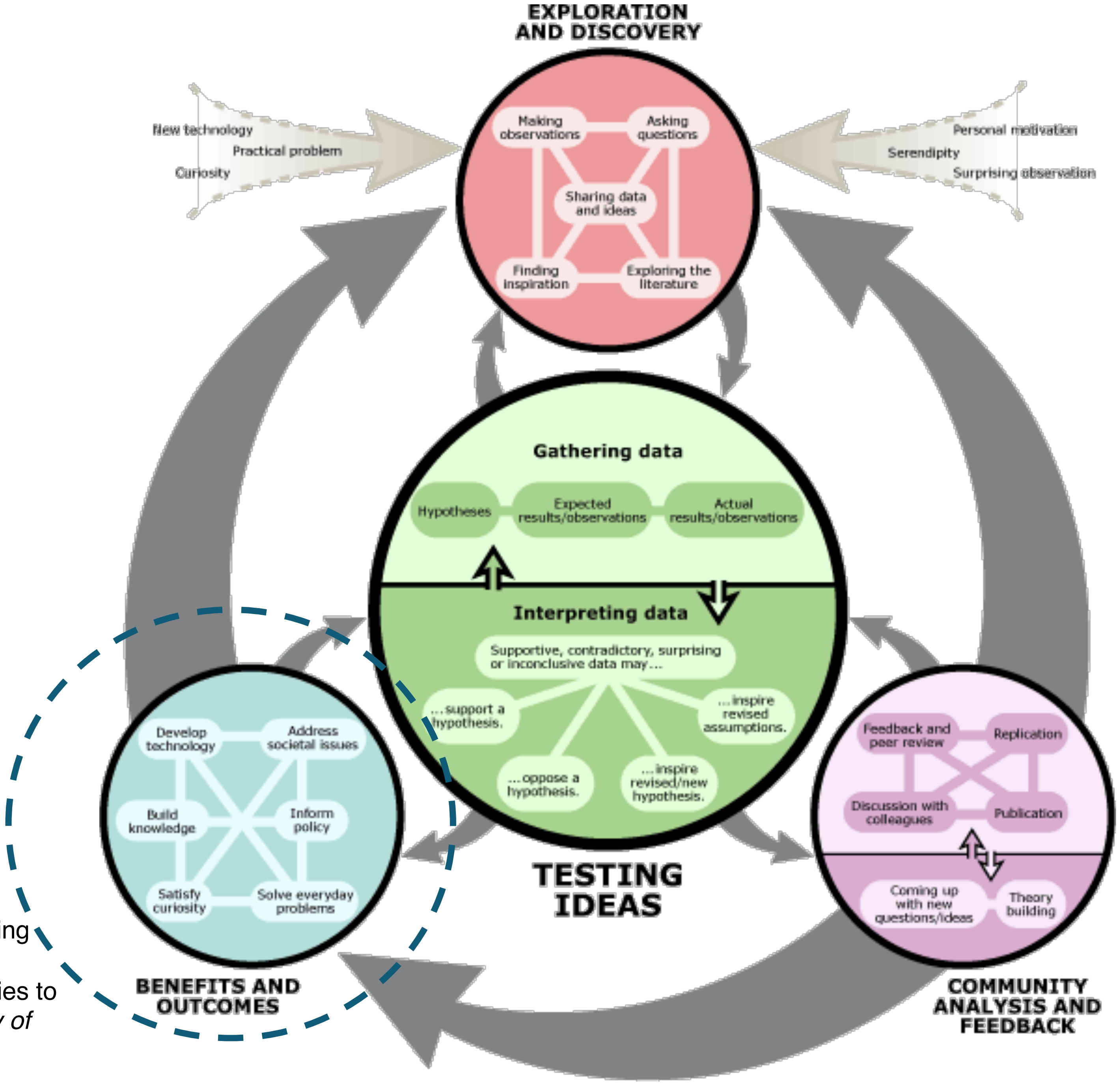
Outside world mostly cares about this part



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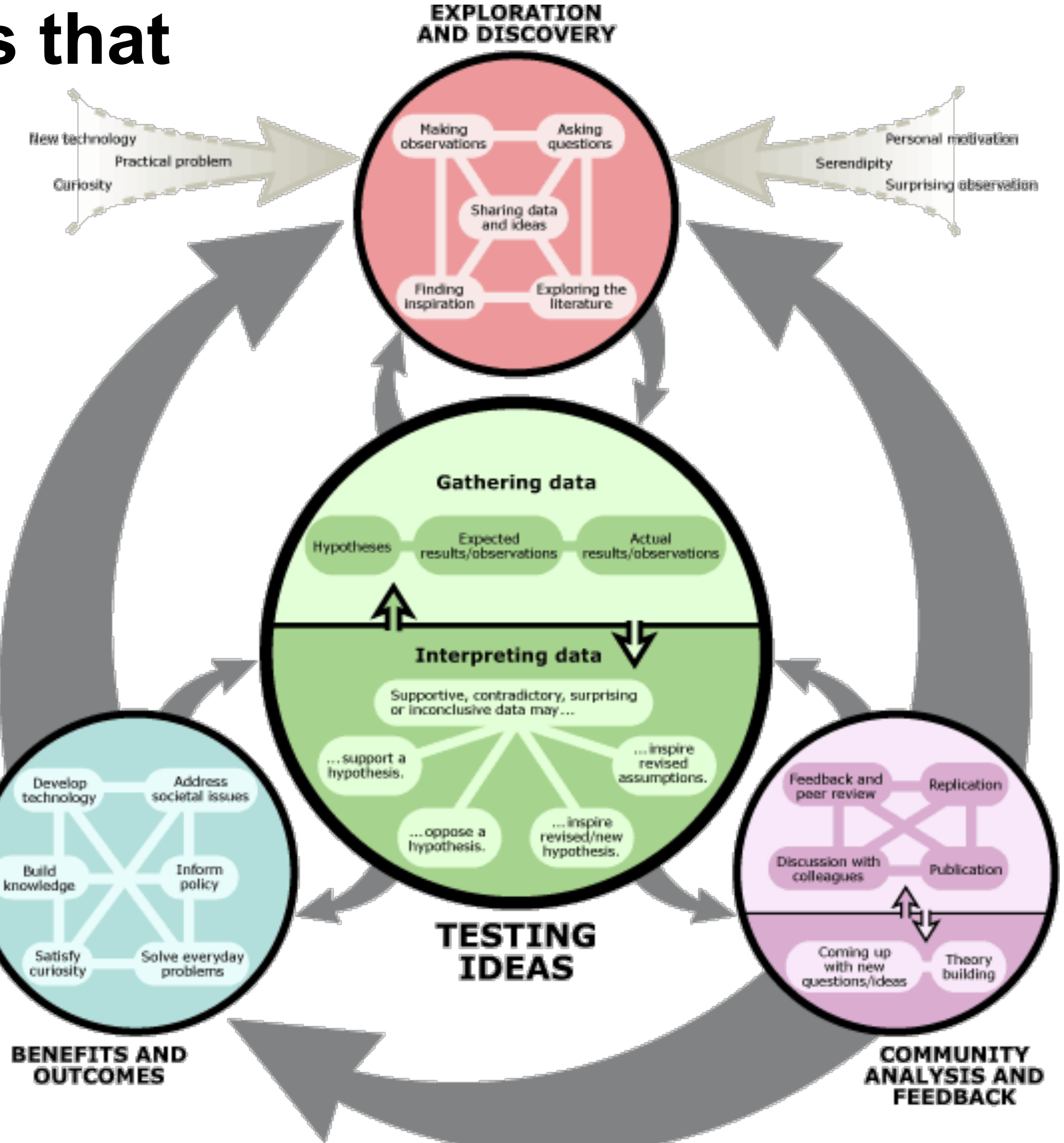
Nuclear data are the arrows that connect (nuclear) science

- Information is not always needed right away
  - Either from an application
  - Or from us, taking another look at old data
- ***There is a need for data stewards***
- Many scientific communities have such data stewards:

DOE's Public Reusable Research (PuRe) Data initiative

(https://science.osti.gov/Initiatives/PuRe-Data)



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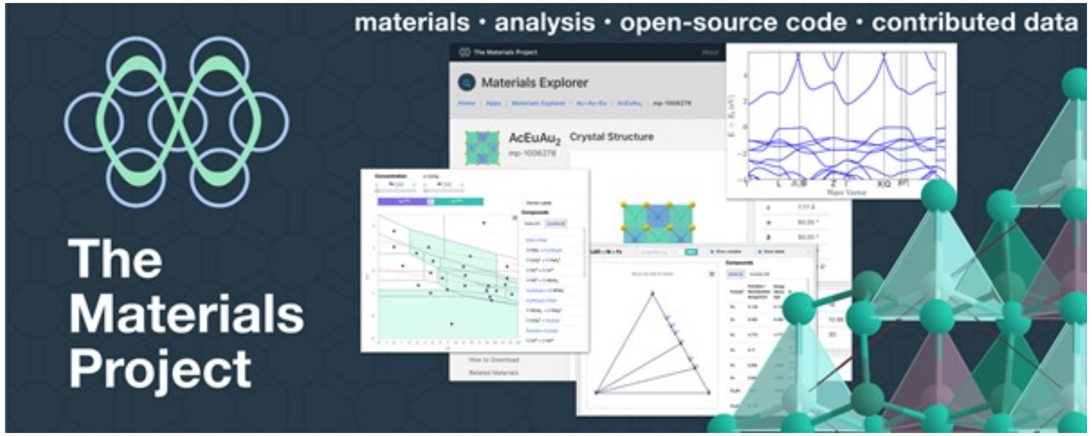
Initial cohort of PuRe data resources



KBase
PREDICTIVE BIOLOGY
DOE Systems Biology Knowledgebase

JGI JOINT GENOME INSTITUTE
A DOE OFFICE OF SCIENCE USER FACILITY

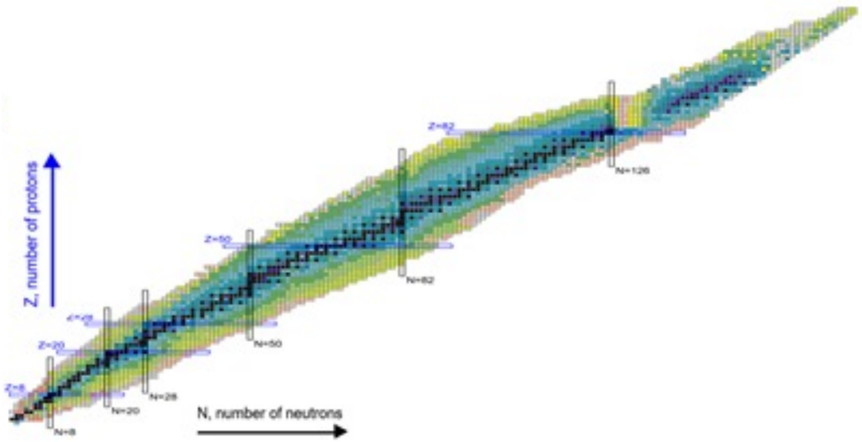
ARM

Most PuRe resources from DOE-BES & DOE-BER

Initial cohort of PuRe data resources

DOE-HEP: Particle Data Group

Review of Particle Properties
Elementary particles & hadron properties
Small overlap with ENSDF (n, p)



DOE-NP: National Nuclear Data Center

Nuclear structure (experimental & evaluated)
Nuclear reactions (experimental & evaluated)
Bibliographic data

Initial cohort of PuRe data resources

There is no PuRe resource specifically for hot/cold QCD

roup

es
on properties
(n, p)

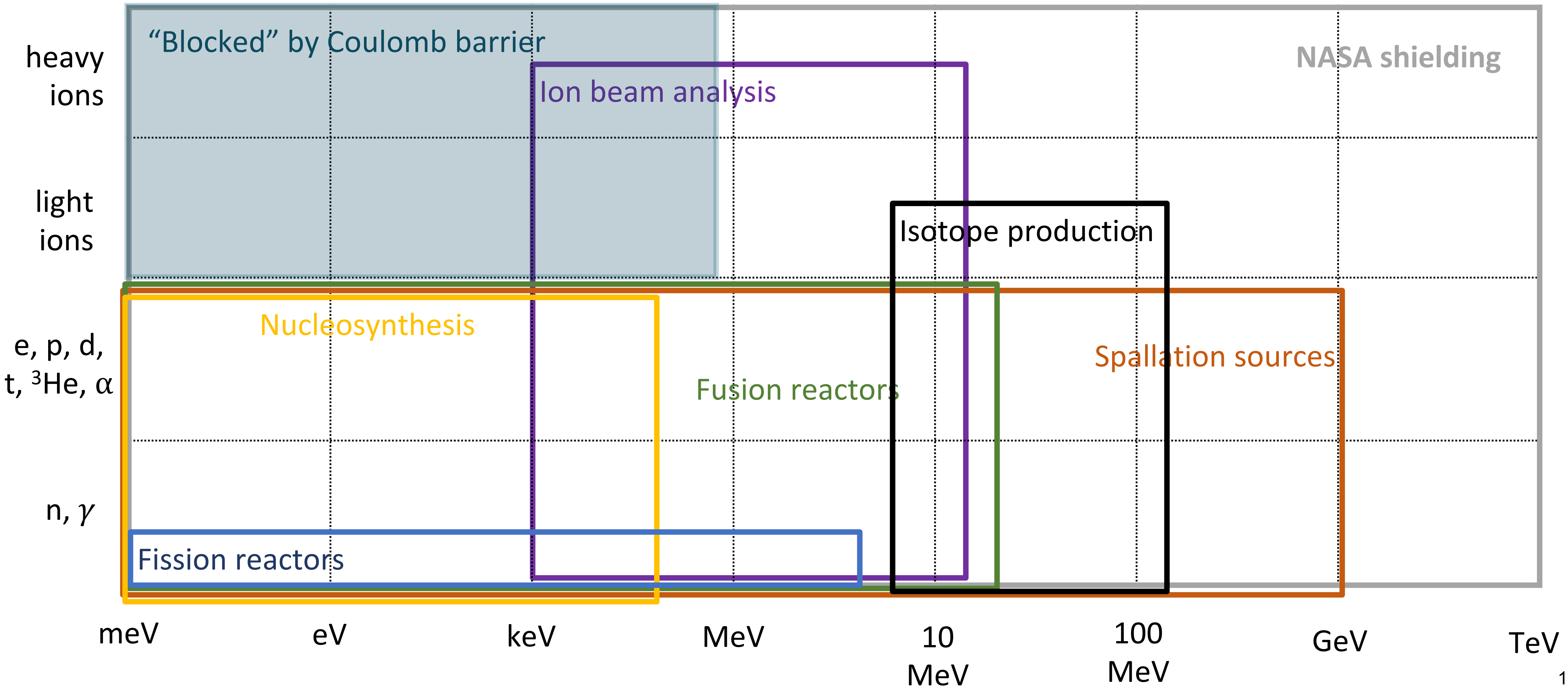
What happens to your data when the experiment turns off?

r Data Center

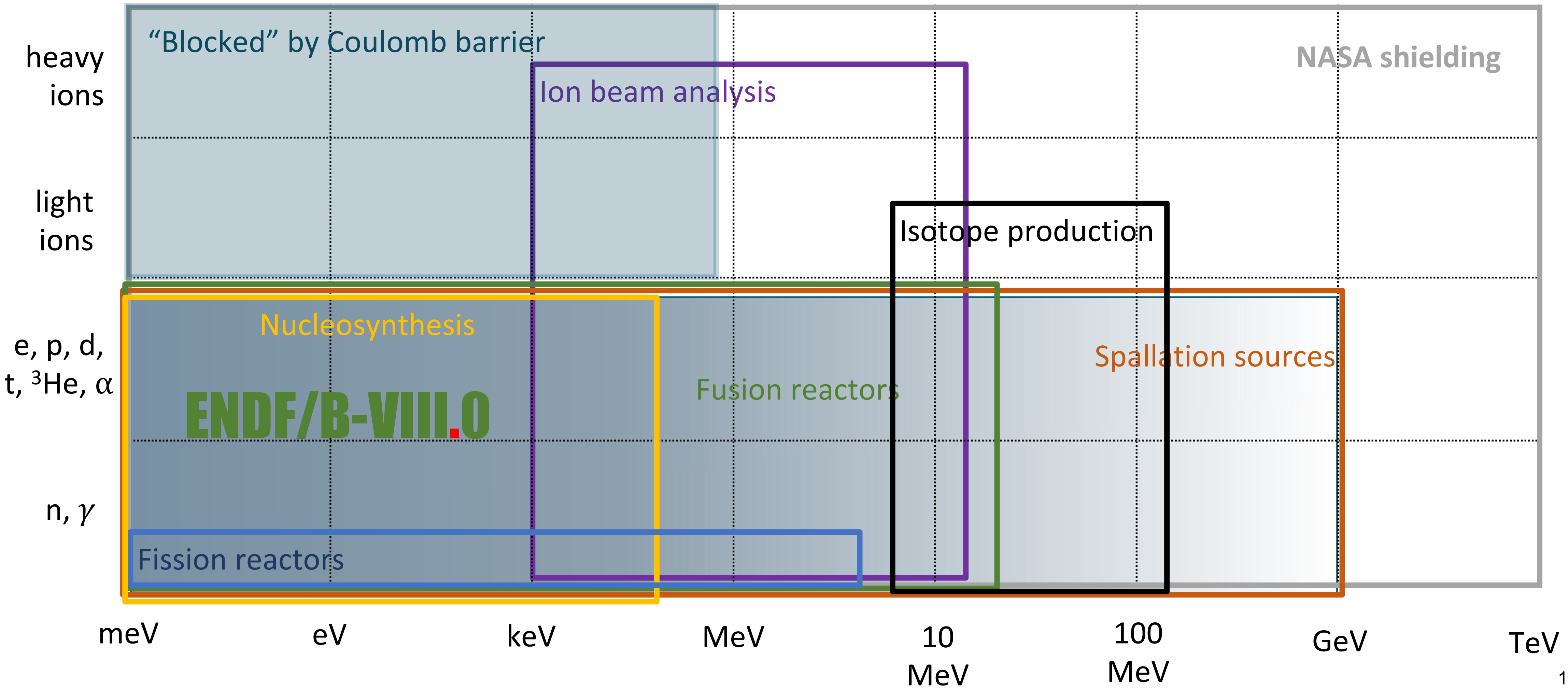
ntal & evaluated)
ental & evaluated)
Bibliographic data

There are real-world applications of high energy heavy ion reaction data

Space shielding applications cover wide swath of energies & projectiles – and overlaps with many other applications!



Evaluated data libraries cover a large range of what is needed, but not all of it!



Transport codes for these applications

FLUKA	FLUKA	INFN (Italy)	http://www.fluka.org/fluka.php	Free reg.
PHITS	PHITS	JAEA (Japan)	https://phits.jaea.go.jp	Open Source
MCNP6	MCNP	LANL	https://mcnp.lanl.gov	Export Controlled, RSICC
GEANT4 A SIMULATION TOOLKIT	GEANT4	CERN	https://geant4.web.cern.ch	Open Source
NASA	HZETRN	NASA	https://software.nasa.gov/software/LAR-18803-1	Export Controlled, NASA, Free reg.

All codes have built in models that cover different physical regimes

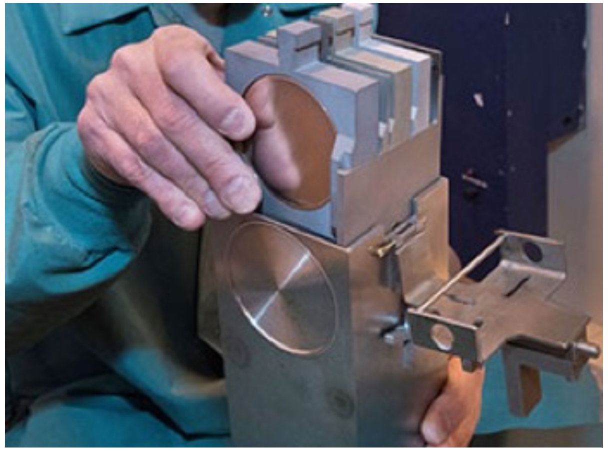
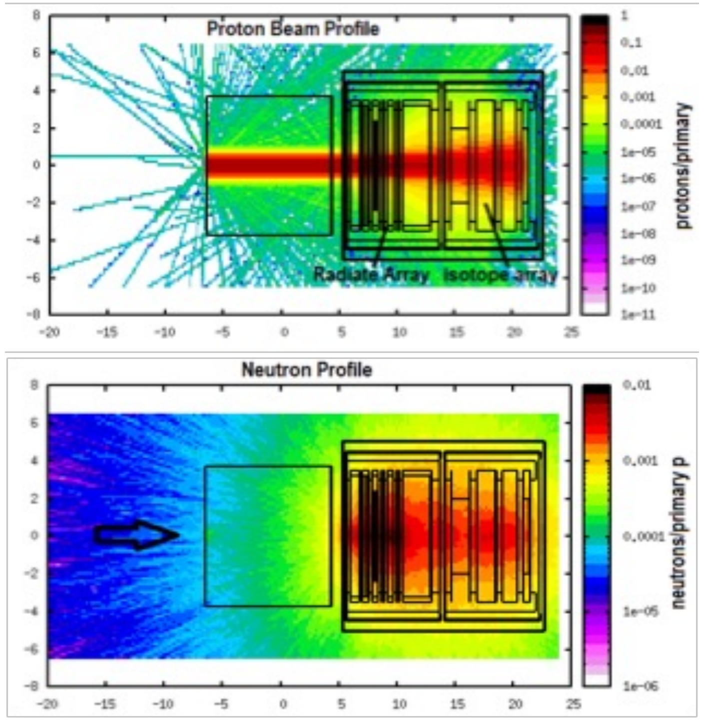
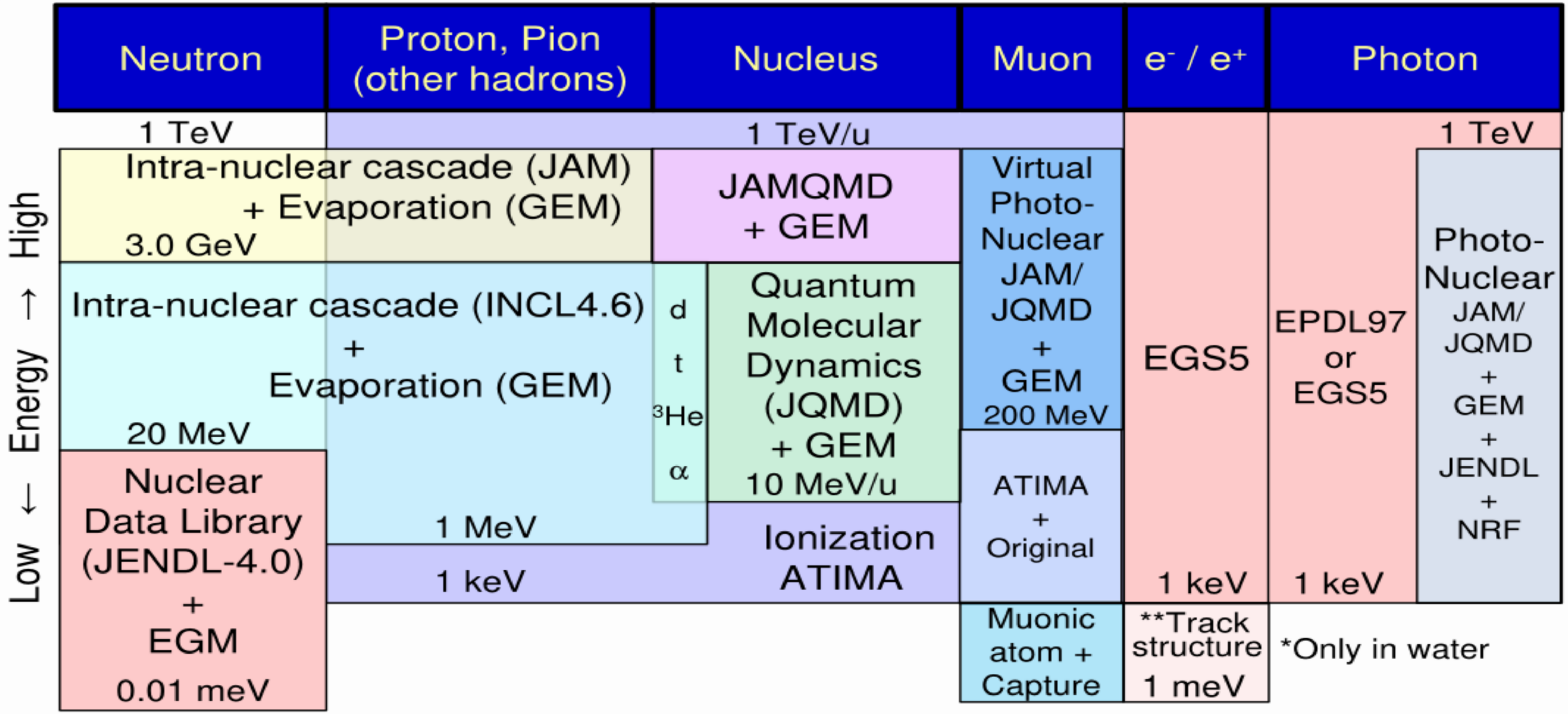


Figure 1: Photograph of a BLIP target stack ready for proton bombardment. (courtesy of C. Cutler)



FLUKA simulation of the BLIP target stack showing the primary proton beam and secondary neutron production (N. Simos (2016))

Map of Models Recommended to Use in PHITS

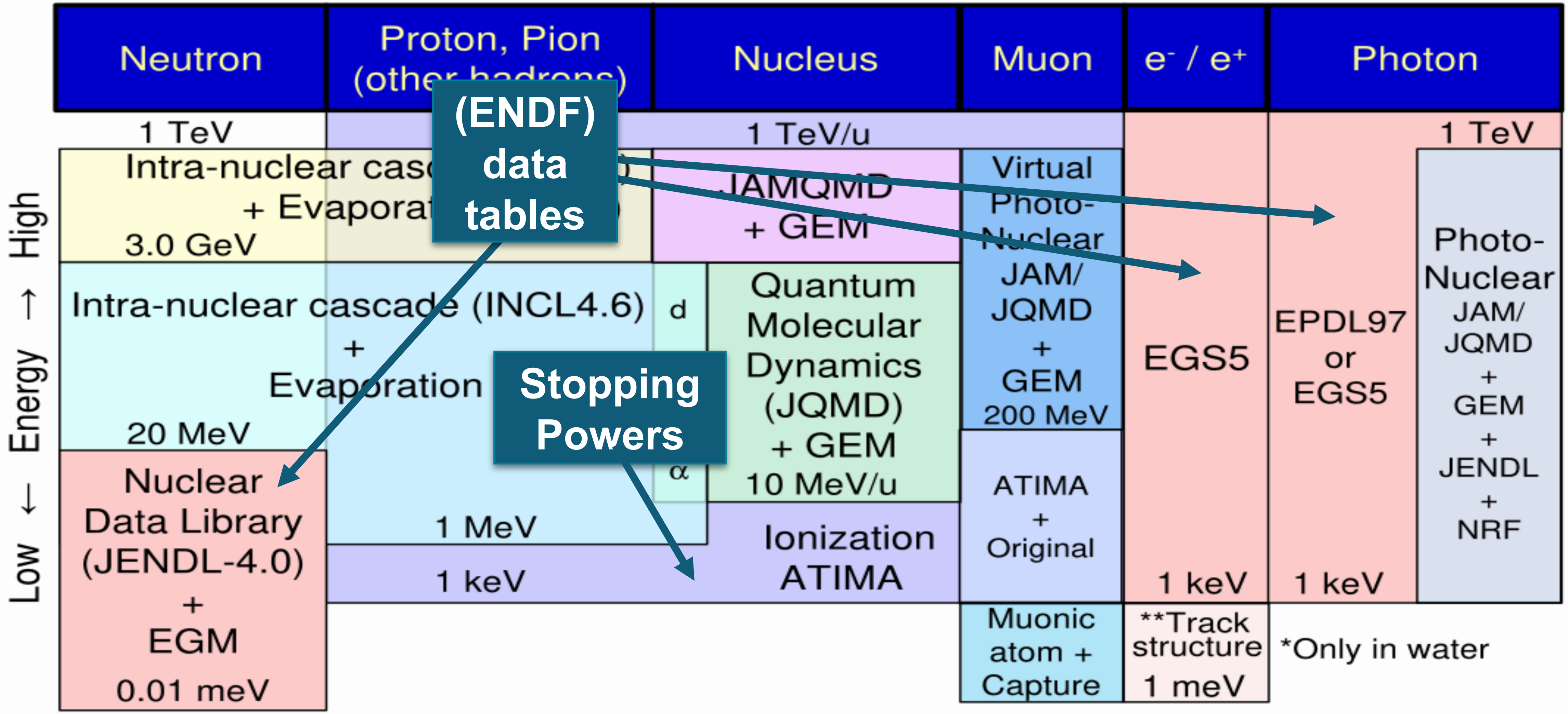


Physics models of PHITS and their switching energies

Switching energies can be changed in input file of PHITS

https://phits.jaea.go.jp/lec/phits-introduction-en.pdf

Map of Models Recommended to Use in PHITS



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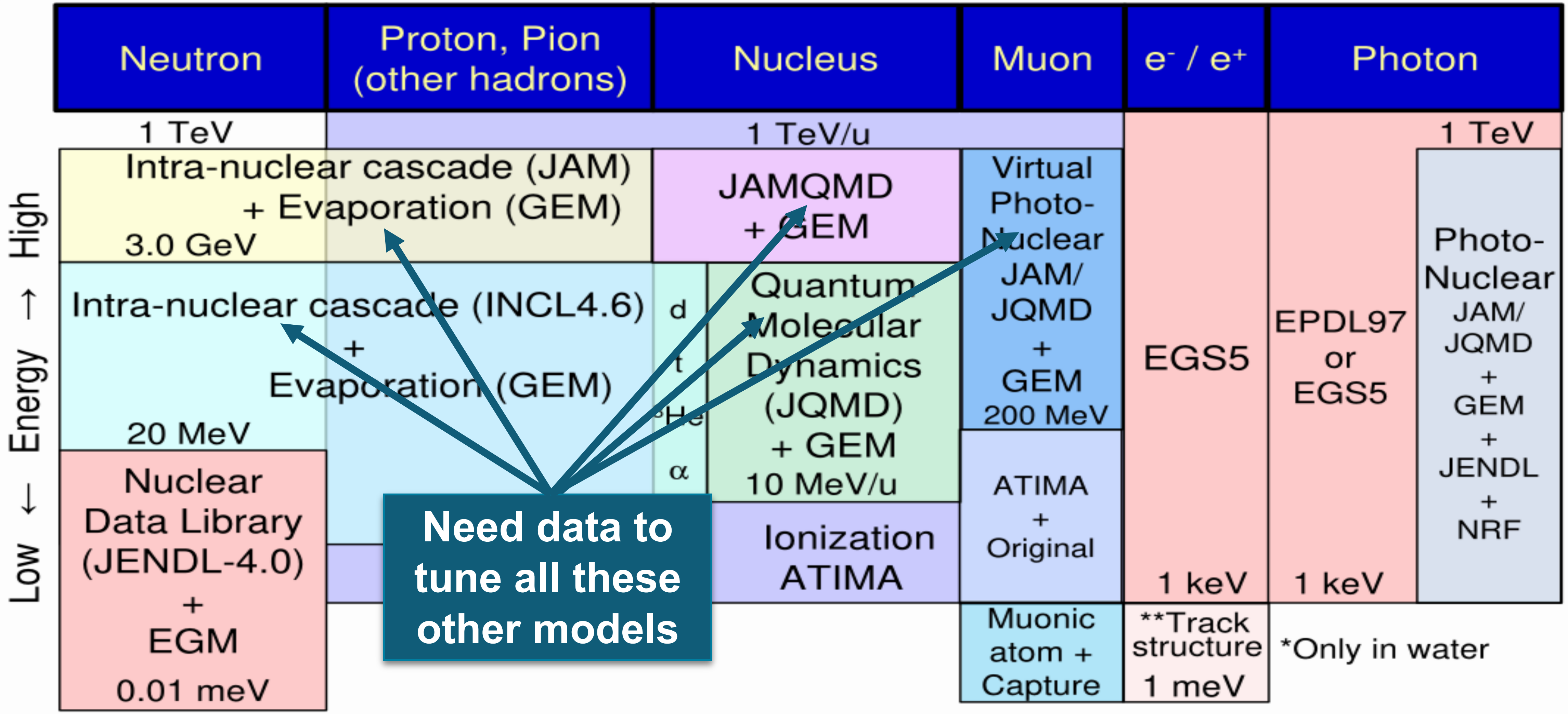

Physics models of PHITS and their switching energies

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https://phits.jaea.go.jp/lec/phits-introduction-en.pdf

What data do these codes need to produce meaningful results?

- Cross sections: Only total cross section and elastic/reaction cross section needed to first approximation
- Particle multiplicities
- Outgoing particle distributions: dN/dE'dΩ
- "Fancy things"- flow, femtoscopy, jets , etc. are unimportant

There is an opportunity ($$) to provide modeling support for these applications!

There are huge gaps in coverage: no heavy-ions, not enough high energy

- **Evaluated (this is what goes in transport codes):**
  - PDG only elementary particle properties
  - CSEWG's ENDF only < 150 MeV + decay data
  - Three major regional data projects (JAEA, US, EU) have made forays into HE
- **Experimental data compilation:**
  - EXFOR/NSR partial tabulation of data/references most comprehensive but poor HE coverage

- Smaller scale projects with basic science & haronic focus:
  - HEPdata,
  - nn-online,
  - GWU DAC
- Pilot project to compile RHIC/AGS data @NNDC circa 2000, but data appears lost
- 3 year ROSSINI3 project (ESA-NASA-GSI) (see https://www.gsi.de/work/forschung/biophysik/fragmentation, https://crosssection-db.herokuapp.com)

Opportunity to collaborate to meet data needs for emerging applications

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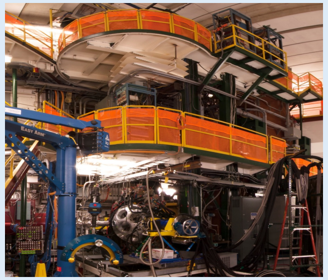
What might a Hot/Cold QCD data program look like?

Current Low Energy Nuclear Physics Data Status

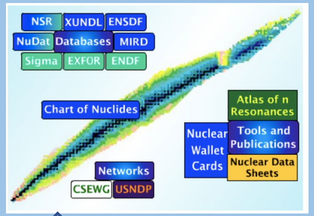
Data collection



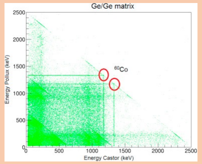
Data storage

- Only a small fraction of experiments are fully preserved. These continue to increase in cost and complexity.
- There is **NO** centralized mechanism for data sharing, resulting in
  - Potential for repeating experiments
  - Data that goes unanalyzed
  - Less resources to plan experiments
  - No opportunity for reproducibility
- Data program parses published tables and digitizes graphs.

Nuclear Databases



Data artifacts



Processed data

Analysis software

ROOT Data Analysis Framework

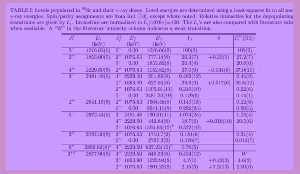
GEANT4 A SIMULATION TOOLKIT

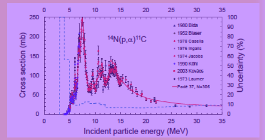
Simulation

Dissemination of Processed Results

arXiv.org

PHYSICAL REVIEW C





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Average experiment costs ~1 million
~300 experiments into XUNDL alone every year

BRIEFING ROOM

OSTP Issues Guidance to Make Federally Funded Research Freely Available Without Delay

AUGUST 25, 2022 • PRESS RELEASES

Today, the White House Office of Science and Technology Policy (OSTP) updated U.S. policy guidance to make the results of taxpayer-supported research immediately available to the American public at no cost. In a memorandum ↗ to federal departments and agencies, Dr. Alondra Nelson, the head of OSTP, delivered guidance for agencies to update their public access policies as soon as possible to make publications and research funded by taxpayers publicly accessible, without an embargo or cost. All agencies will fully implement updated policies, including ending the optional 12-month embargo, no later than December 31, 2025.

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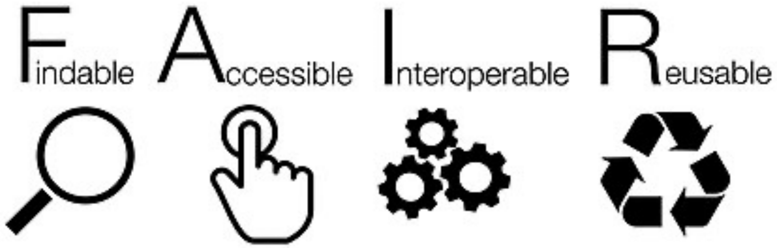
https://www.whitehouse.gov/ostp/news-updates/2022/08/25/ostp-issues-guidance-to-make-federally-funded-research-freely-available-without-delay/

The OSTP mandate isn't enough

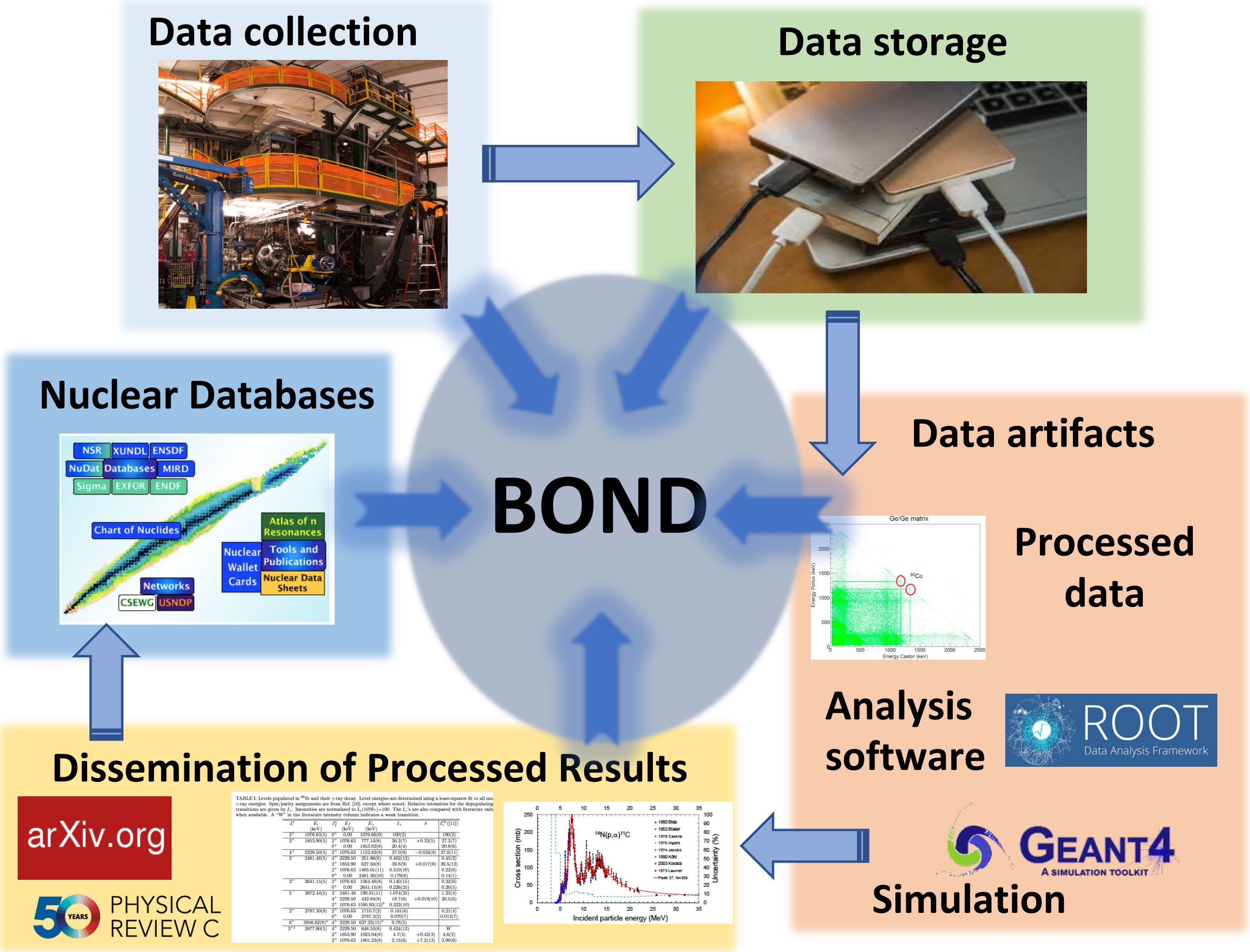
- **Yes, all published papers should be made Open Access, with all data from plots in machine readable data tables, but this is the bare minimum**

- **Data must be future proofed – you don't know what others (or your future self) will need in a future analysis**
  - Need to preserve as much of the original analysis and data as is practical
  - This data & analysis codes should follow FAIR principals
  - Time scale of preservation is >> 20 years, our experience suggests it is closer to 100 years



- **This is real point of the Data Management Plans for all new DOE-NP proposals**

Brookhaven Open Nuclear Data (BOND)



BOND will ingest, document, and preserve data at each stage of an experiment

Major goals include

- Establish repository of low-energy nuclear data at NNDC
- Implement FAIR principles
- Leverage BNL computing, AI/ML expertise & NNDC expert knowledge
- Integrate NNDC in Data Management Plans
- Piloting with FRIB
- Work backwards to legacy data

Could a variant of this concept work for Hot/Cold QCD community?

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Other connections between Hot/Cold QCD and nuclear data

- Physics connections:
  - Measure nuclear deformations using flow in high energy heavy ion reactions; Accessing charge radii & neutron skins (https://arxiv.org/abs/2209.11042) – Jianyoung Jia
  - Access exotic nuclear states using ultraperipheral collisions – Spencer Klein
- Common tools such as AI/ML
- Common detector systems (NIFFTE – a TPC for nuclear fission!)
- DEI is an issue for all of us!