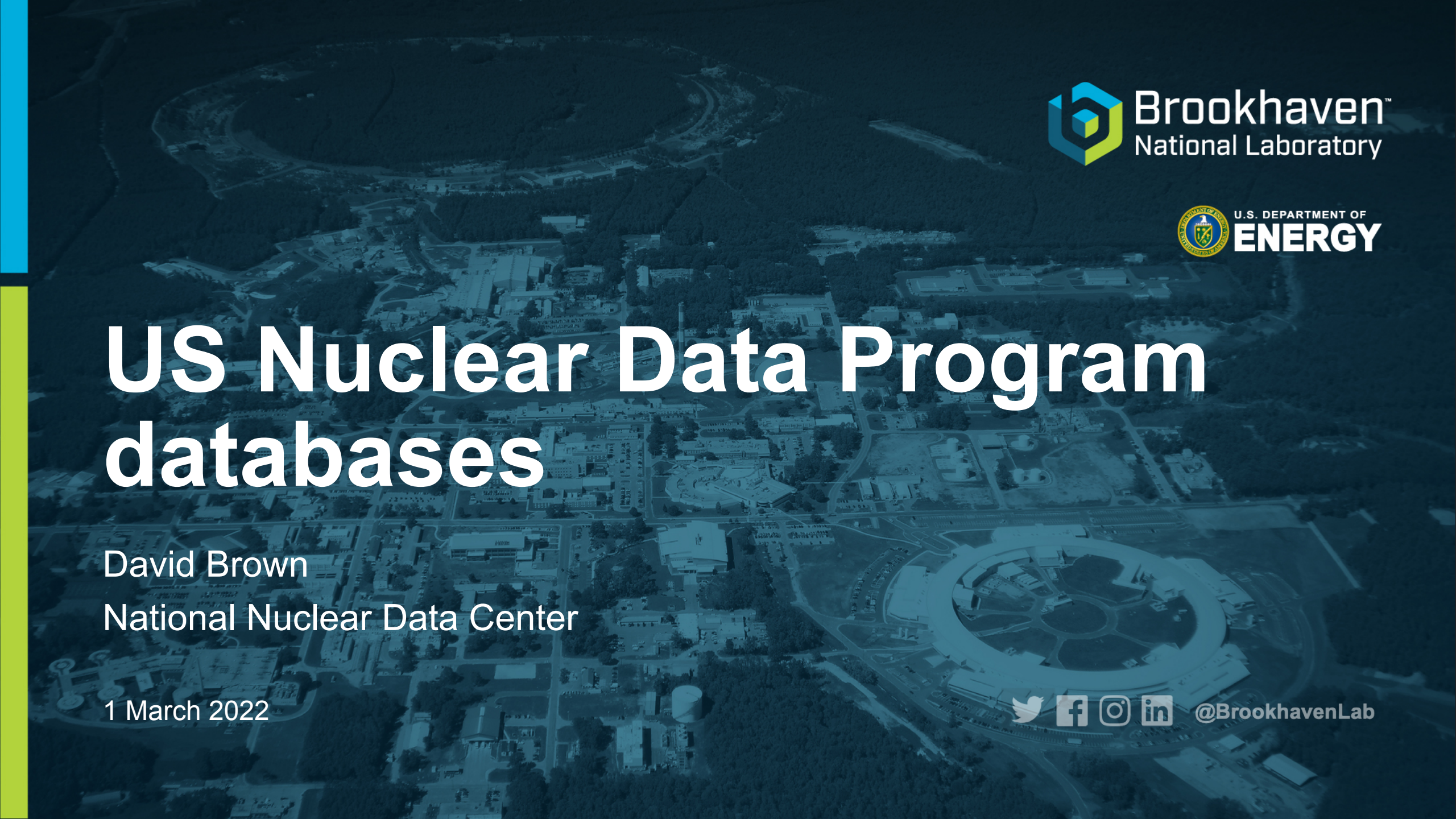

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U.S. DEPARTMENT OF ENERGY

US Nuclear Data Program databases

David Brown

National Nuclear Data Center

1 March 2022

@BrookhavenLab

Transport codes for shielding 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	EC, 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	EC, NASA, Free reg.

All codes have built in models that cover different physical regimes

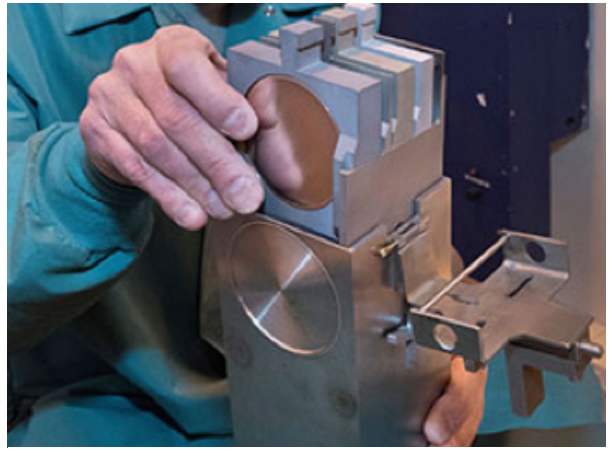
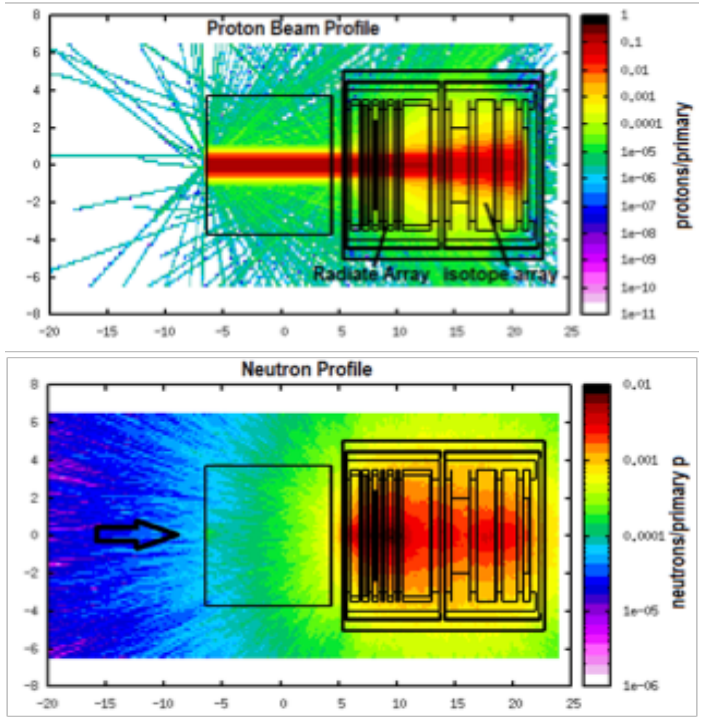
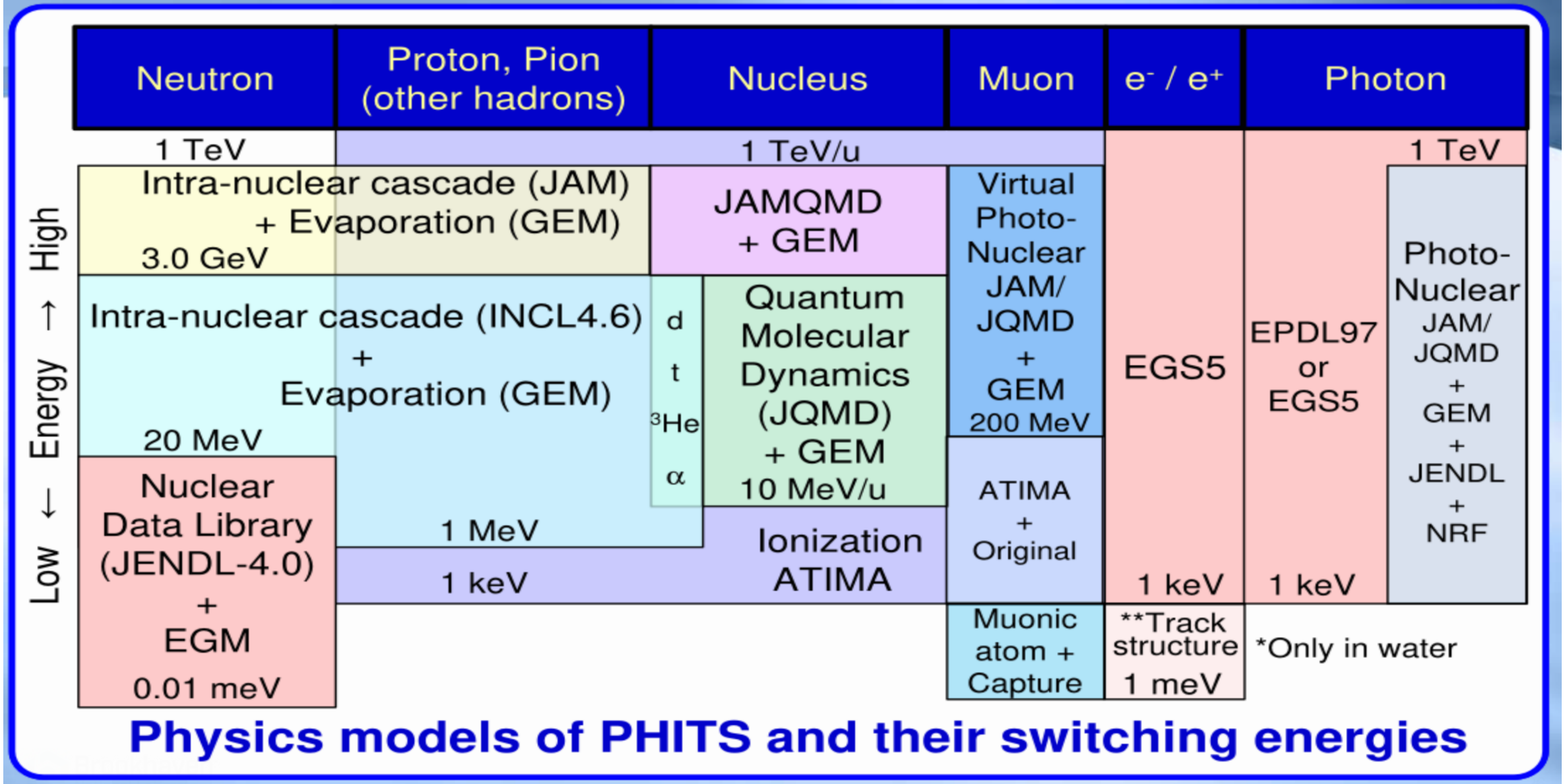


Figure 1: Photograph of a BLIP target stack ready for proton bombardment. (courtesy of C. Cutler)



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

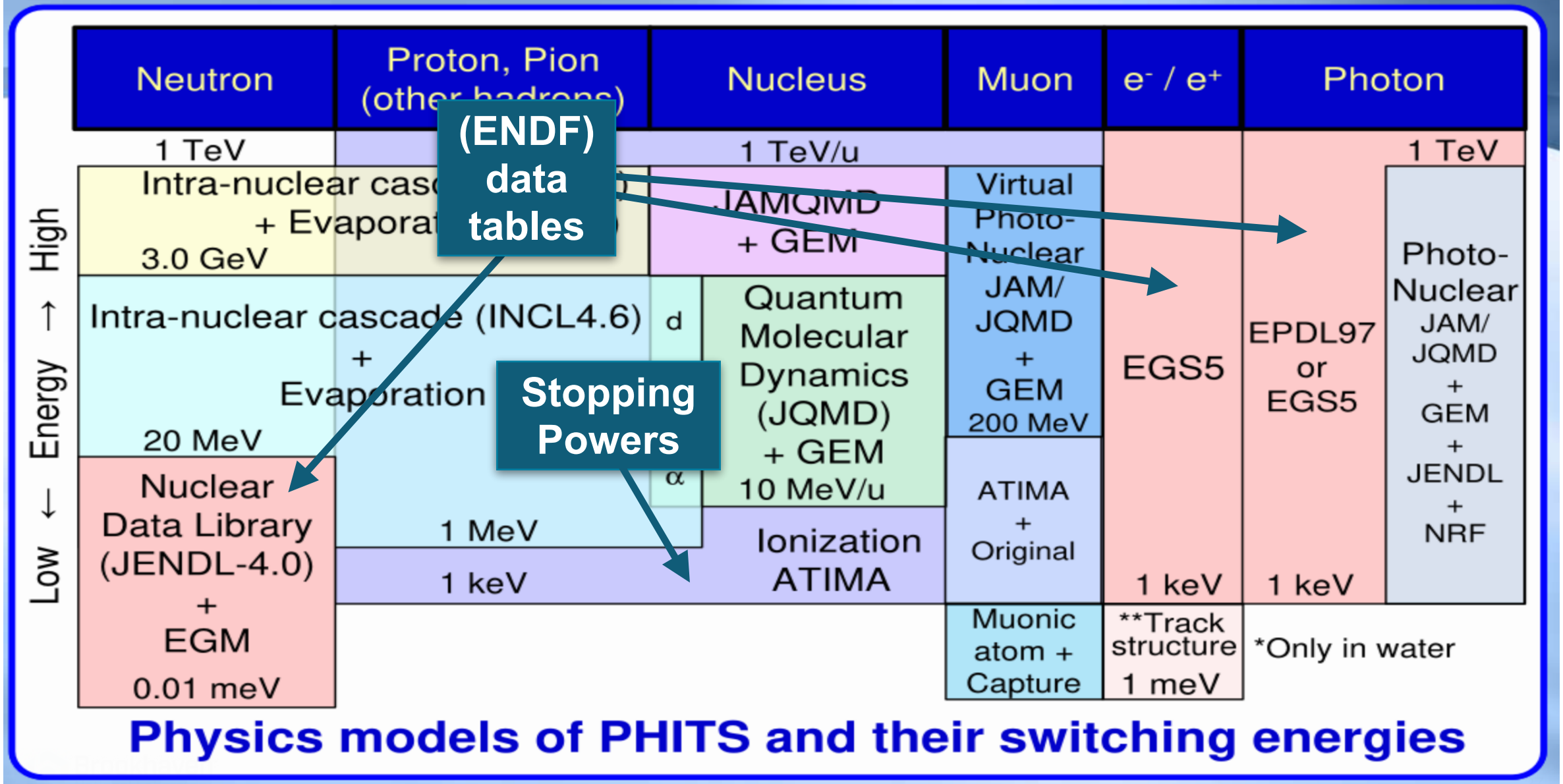


Physics models of PHITS and their switching energies

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

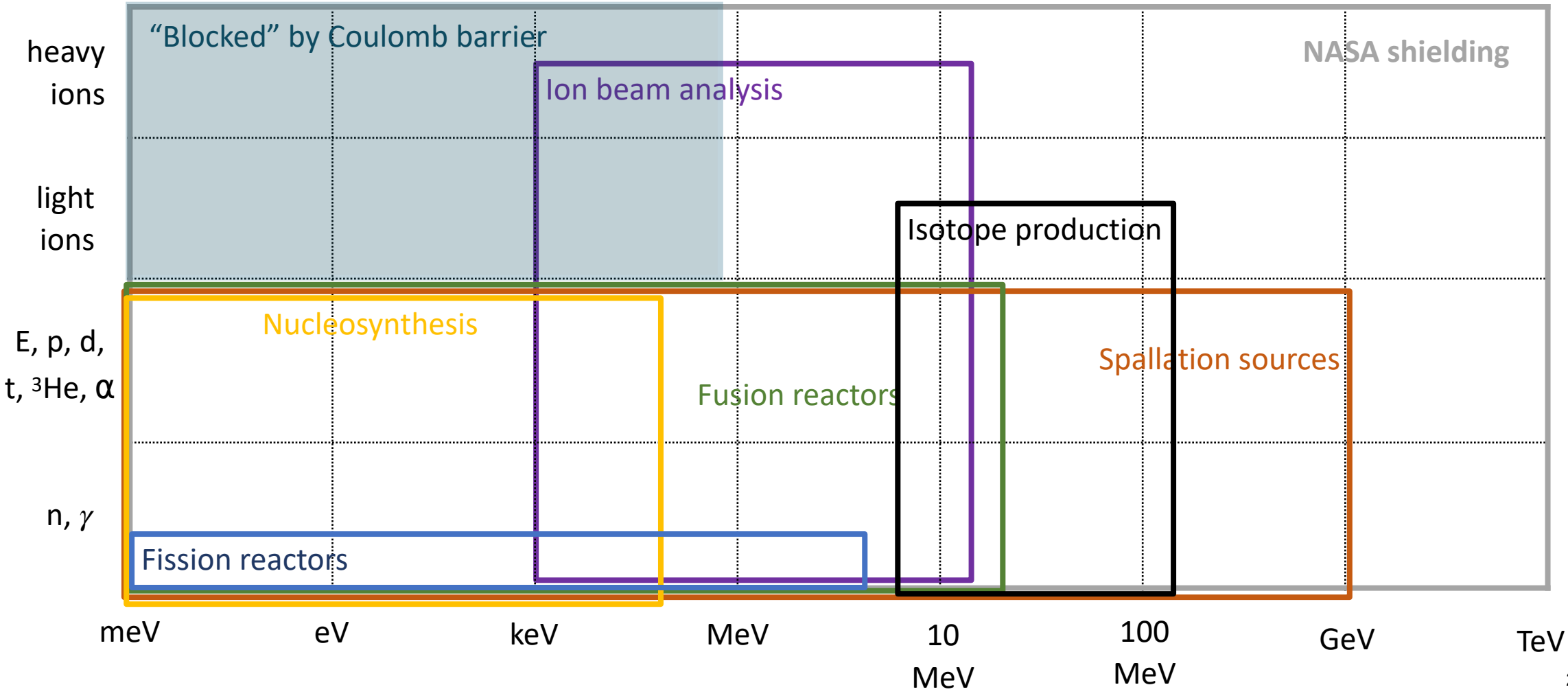


Physics models of PHITS and their switching energies

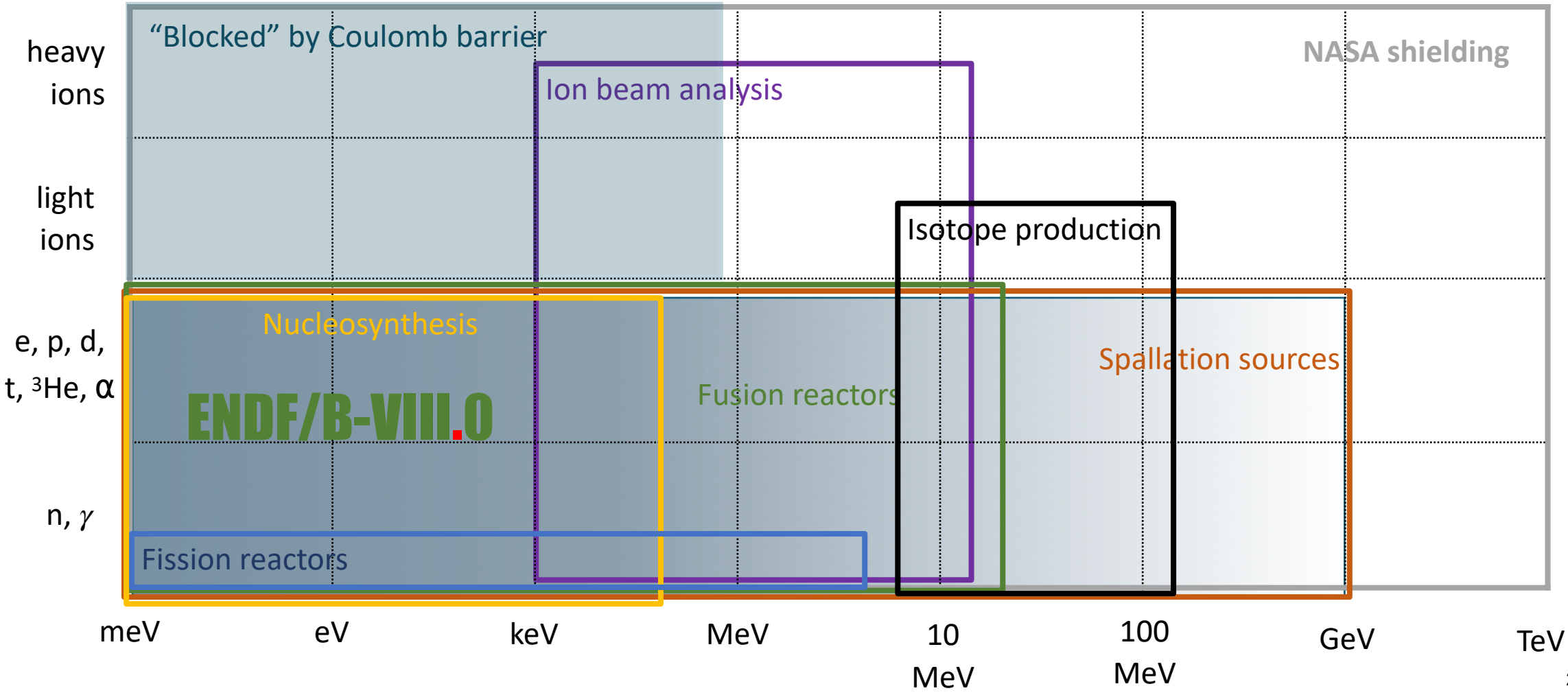
Switching energies can be changed in input file of PHITS

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

Space shielding applications cover wide swath of energies & projectiles



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



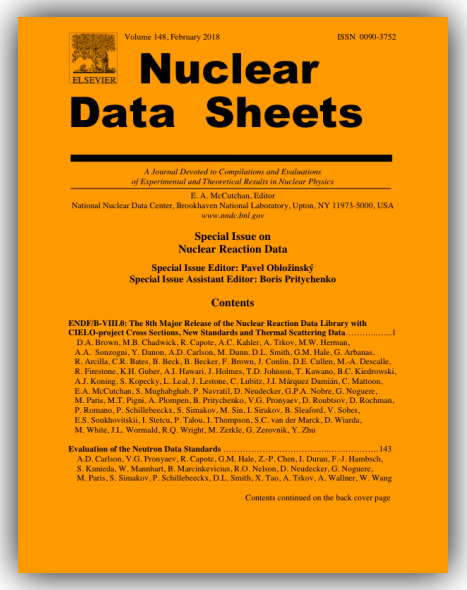
Data tables from ENDF libraries power the low energy portion of these simulations

- Neutrons up to 30-150 MeV (depending on nucleus)
- Light charged particles (p, d, t, ^{3}He, α) up to 30 MeV (150 MeV for p's)
- Electrons up to 1 GeV (atomic)
- Photons
  - up to 1 GeV (atomic)
  - 100 MeV photonuclear
- Decay data

ENDF/B VIII.1

(In development, planned Feb. 2024)

Recommended values combining theory, experiment w/ ML glue



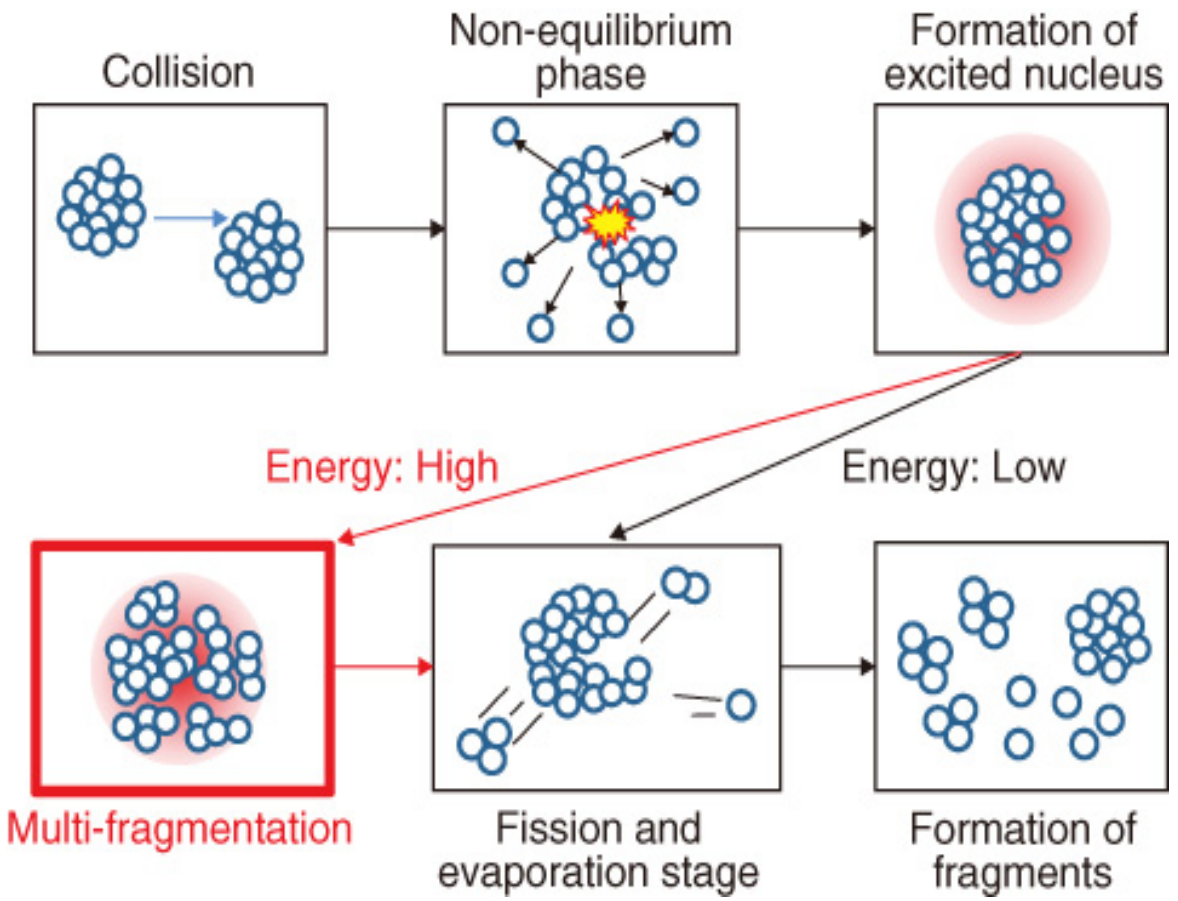
2018 special issue detailing ENDF/B-VIII.0. 755 citations (Google Scholar)

Improved modeling in the 100 MeV/A-1 GeV/A region

Cross over from Hauser-Feshbach & multistep direct/ compound theory to multifragmentation

Corresponds to liquid-gas phase transition in heavy-ions

Theory well developed, but needs tuning to extrapolate to all relevant systems



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Improved modeling above 1 GeV/A?

Punch through achieved!

Nuclei are obliterated!

Only total, elastic and reaction cross sections, multiplicities and energy-angle distributions needed

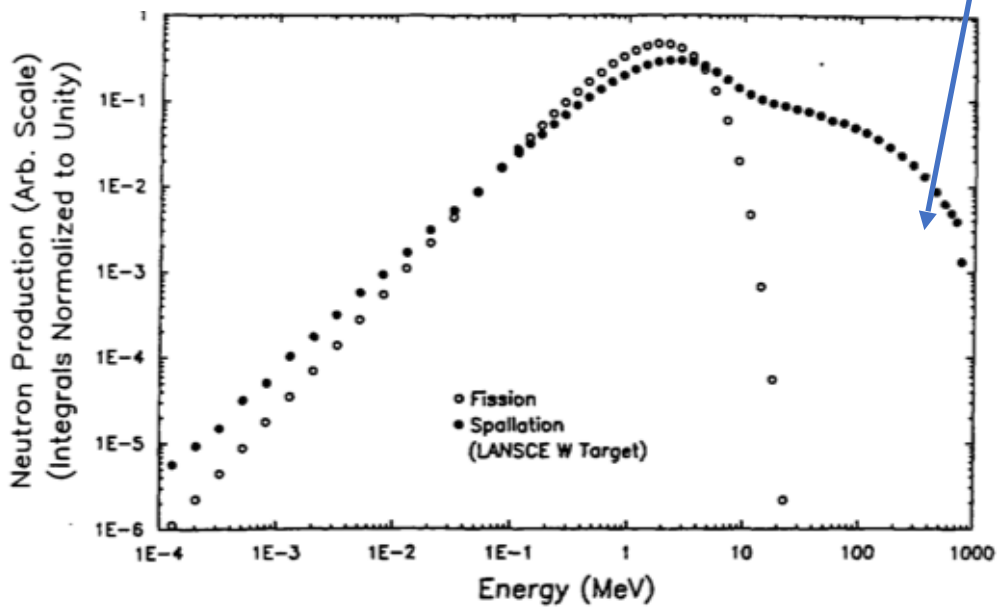

Figure 6. Neutron production from fission (○) and from spallation (●).

Neutron Production from LANSCE Tungsten Split−Target
Bombarded by 800−MeV Protons

G. Russel, "Spallation Physics – An Overview", ICANS-XI International Collaboration on Advanced Neutron Sources KEK. Tsukuba. October 22-26,1990

BlastWave, Therminator, etc. level modeling may be enough!

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: $dN/dE'd\Omega$

"Fancy things"- flow, femtoscopy, jets , etc. are unimportant

There is an opportunity to provide modeling support for shielding applications!

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

Opportunity to collaborate to meet data needs for space physics