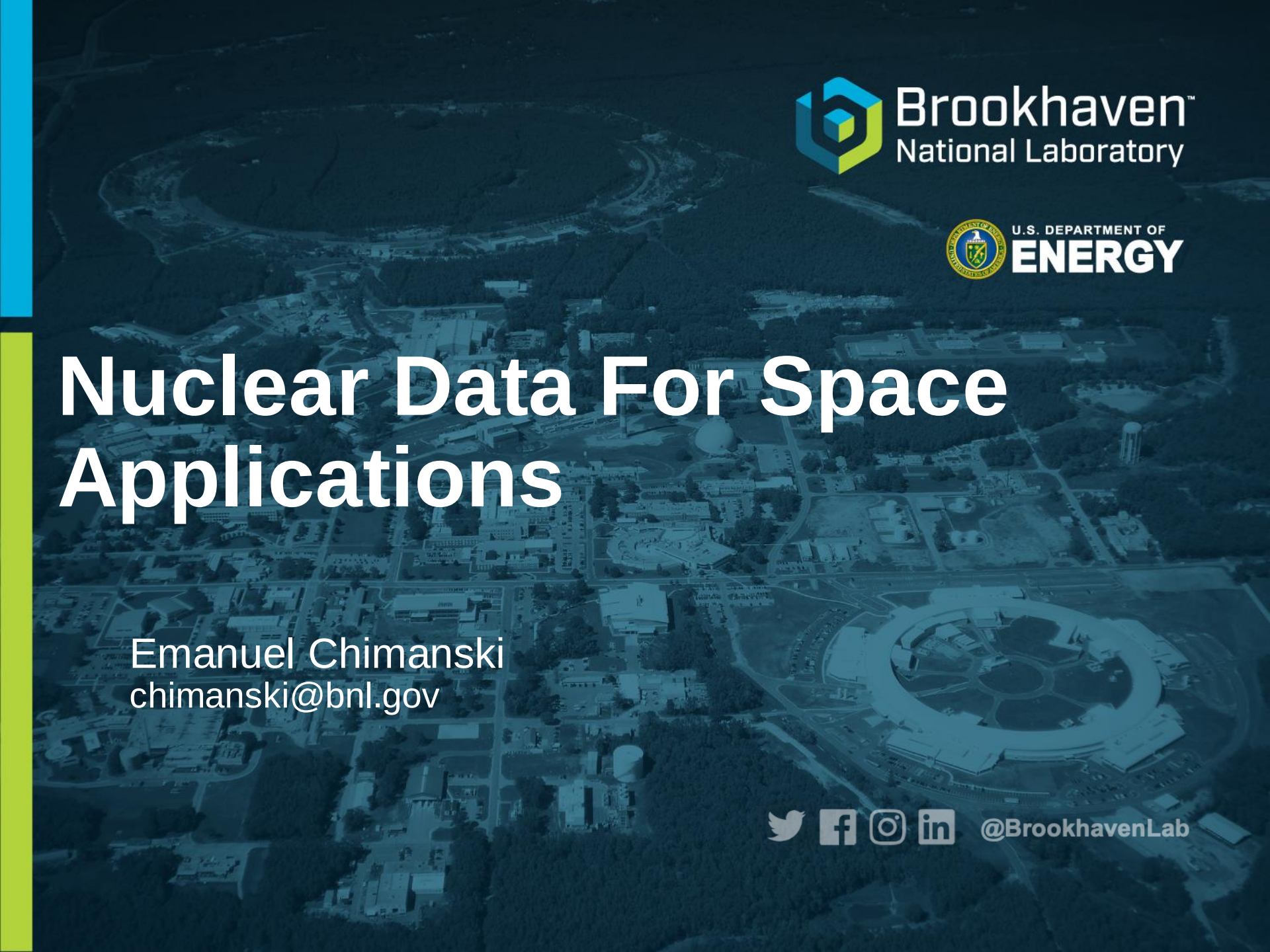

Nuclear Data For Space Applications

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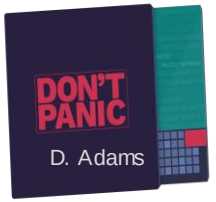
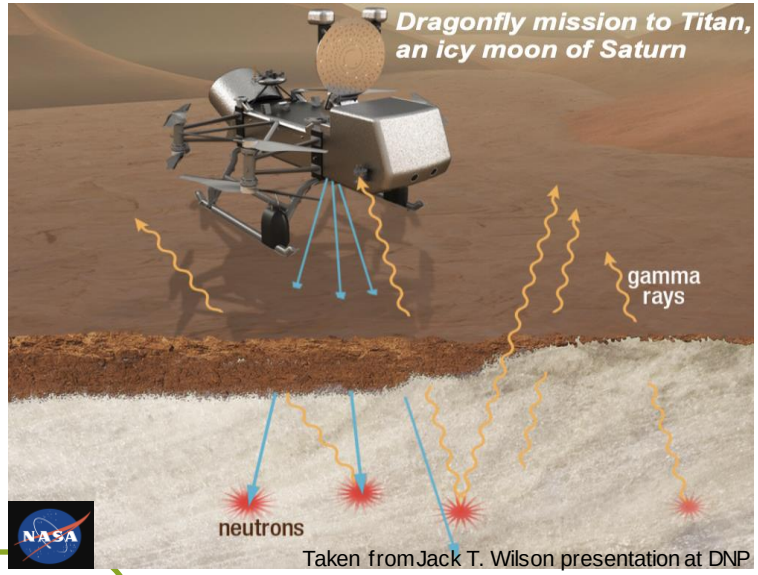
Planetary Nuclear Spectroscopy:
Space exploration and beyond!



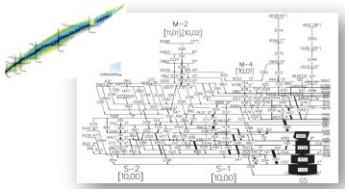
from wiki

- **Active Interrogation with fast neutron beams;**
  En = 14 MeV
- **Capture, Inelastic and Decay Gammas**
  Nuclear fingerprints
- **Subject to**
  - Thorough experimental knowledge;
  - Precise models and evaluations;
  - Incorporation of data into evaluated files;



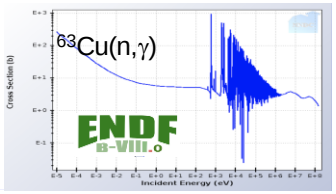
Taken from Jack T. Wilson presentation at DNP

ENSDF
Evaluated Nuclear Structure Data File



measured data

+



ENDF
Evaluated Nuclear Data File

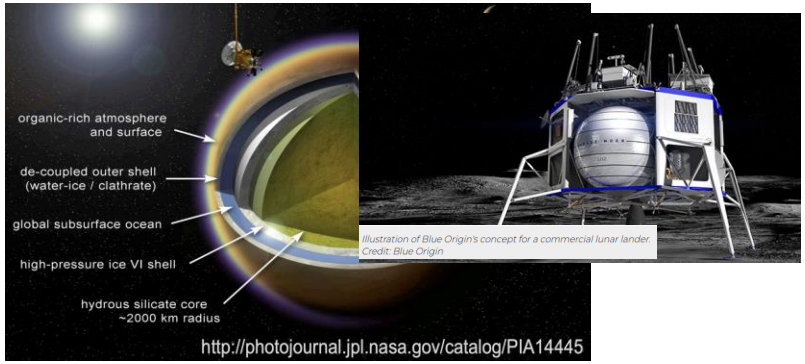
Experimental supplemented with theoretical data
Gamma Ray spectra

More at
NASA Goddard
1.36M subscribers
https://dragonfly.jhuapl.edu/

Neutron Interrogation for Material Characterization is strongly dependent on gamma ray production libraries

Space exploration: Today and tomorrow!

- **<u>Upcoming Missions</u>**:
- LunaH Map (2022)
- Psyche (2023)
- VIPER (2023)
- MMX (2024)
- **Dragonfly (2026)**
- Commercial Lunar Payload Services (multiple payloads/missions, 2022)



Deficiencies in neutron cross-section and photon atomic data libraries have been noted in the literature

- Yamashita et al. (2003), Adv. Space Res. 31;
- Prettyman et al. (2006), JGR 111 ;
- Brückner et al. (2011) NIMB 269;
- Lim et al. (2017) Met. Planet. Sci. 52;
- Han et al. (2018). IEEE Trans Nucl Sci, 65;
- Mauborgne et al. (2020), EPJ Web Conf., 239;

Archaic formats;
Lack of intrinsic consistency;
Outdated (possible mistakes) values;
Missing documentation;
Protocol for version management

NASA currently has numerous active and upcoming investigations valued at >$100M.

Space applications are evoking outdated evaluations that need to be revisited

The accuracy of the simulations varies strongly depending on neutron inelastic cross section library is used

Model Accuracy
Within 5%
Within 5-10%
Within 10-20%
Diff. >20%
"--" = No Peak in Model

Model/Measurement Ratio

	Gamma Ray (keV)	G4NDL 4.6	G4NDL 4.5	ENDF VIII	ENDF VII	ENDF VI	JENDL 4.0	JENDL 3.3	CENDL 3.1	BROND 3.1
H	2223	1.45±0.01	1.47±0.01	1.44±0.01	1.47±0.01	1.45±0.01	1.44±0.01	1.46±0.01	1.46±0.01	1.45±0.01
C	4438	1.40±0.03	1.36±0.03	1.34±0.03	1.37±0.03	1.30±0.03	1.47±0.03	1.38±0.03	1.41±0.03	1.38±0.03
O	6129	0.78±0.06	0.71±0.05	0.05±0.01	--	--	0.71±0.05	0.70±0.05	0.70±0.70	0.06±0.01
Na	440	1.13±0.03	0.45±0.01	0.25±0.01	0.25±0.01	0.25±0.01	1.26±0.03	1.26±0.03	--	1.17±0.03
	1634	1.92±0.03	1.73±0.17	--	--	--	1.66±0.02	1.69±0.02	--	2.06±0.03
Mg	1369	1.42±0.02	1.42±0.02	1.41±0.02	1.41±0.02	--	1.40±0.02	1.40±0.02	0.86±0.02	1.42±0.02
Al	843	1.22±0.01	1.07±0.01	1.09±0.01	1.10±0.01	1.11±0.01	1.09±0.06	1.05±0.01	1.05±0.01	1.11±0.01
	1014	1.47±0.01	1.32±0.01	1.31±0.01	1.31±0.01	1.30±0.01	1.22±0.08	1.22±0.00	1.20±0.00	1.31±0.01
	2211	1.21±0.01	1.18±0.01	1.18±0.01	1.12±0.01	1.12±0.01	1.01±0.01	0.98±0.01	0.94±0.01	1.14±0.01
Si	1779	1.05±0.02	1.12±0.02	1.13±0.02	1.13±0.02	1.13±0.02	0.07±0.00	1.07±0.02	1.13±0.02	1.13±0.02
S	2232	1.31±0.01	0.78±0.01	--	0.78±0.01	0.80±0.01	0.79±0.01	0.79±0.01	--	0.80±0.01
Cl	1763	0.99±0.01	1.02±0.01	1.03±0.01	1.02±0.01	1.02±0.01	--	--	--	1.10±0.02
Ca	3736	1.00±0.04	--	--	--	0.06±0.01	--	1.12±0.04	0.04±0.01	--
Ti	983	1.07±0.03	1.06±0.03	1.06±0.03	1.05±0.03	--	1.07±0.03	1.08±0.03	1.09±0.03	1.05±0.03
Fe	846	0.88±0.01	0.94±0.01	0.99±0.01	0.94±0.01	0.94±0.01	0.95±0.01	0.95±0.01	0.90±0.01	1.06±0.02
	1238	0.71±0.03	0.80±0.03	0.83±0.03	0.81±0.03	0.77±0.03	0.85±0.03	0.87±0.02	0.67±0.03	0.75±0.09
	1408	1.14±0.07	0.91±0.06	0.89±0.06	0.83±0.06	0.78±0.06	0.94±0.06	0.92±0.05	0.88±0.06	1.27±0.19
Co	1099	1.28±0.04	1.30±0.04	0.93±0.04	--	--	--	0.88±0.04	--	0.84±0.05
	1190	1.13±0.02	1.15±0.02	1.08±0.02	--	--	--	0.85±0.02	--	0.86±0.02
	1292	1.31±0.06	1.32±0.05	1.93±0.05	--	--	--	1.40±0.06	--	1.37±0.07
	1459	1.71±0.04	1.67±0.04	0.86±0.03	--	--	--	0.67±0.03	--	0.65±0.03
	1481	1.24±0.06	1.20±0.05	1.02±0.05	--	--	--	0.89±0.05	--	0.95±0.07
Ni	1332	1.02±0.01	1.11±0.02	1.03±0.01	1.10±0.02	1.09±0.01	0.91±0.01	0.90±0.01	1.05±0.01	1.00±0.01
	1454	0.84±0.02	0.87±0.02	0.93±0.02	0.89±0.02	0.87±0.02	0.73±0.02	0.72±0.01	0.99±0.02	0.86±0.01

Highlighted cases from Jack T. Wilson presentation at DNP2022

ENDF does a good job but it's not yet shining

Opportunity to have broader suite of benchmarks and achieve a more complete validation of nuclear data

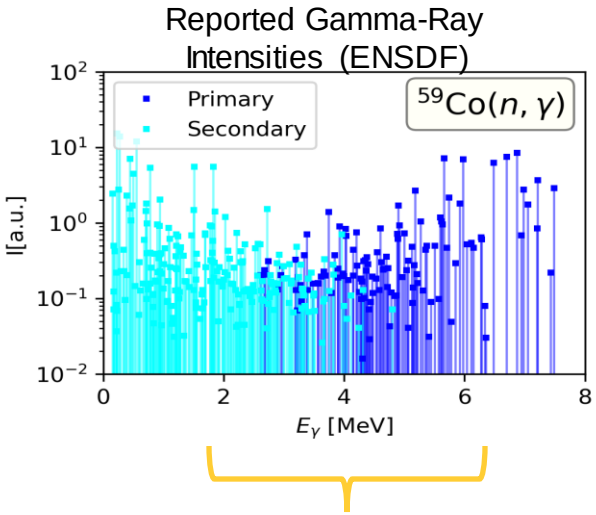
A Joint Effort:
Experiment + Evaluations + Validation

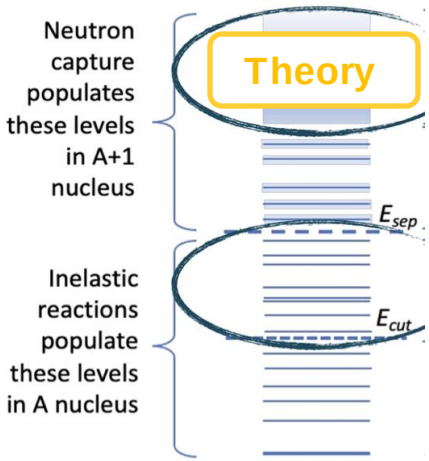
Space Application Needs

(Gamma Ray Spectra)

- Capture Gamma Rays
- Inelastic Gamma Rays
- Gamma Rays from pseudo-continuum

for isotopes lighter than Cu





We can take the chance to improve the Intermediate energies given by theory

Opportunity:
Measurements and evaluations can finally be performed at same time!!

Thank you

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