Oak Ridge National Laboratory

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WANDA-25
Fusion Energy Science Summary

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U.S. DEPARTMENT OF ENERGY

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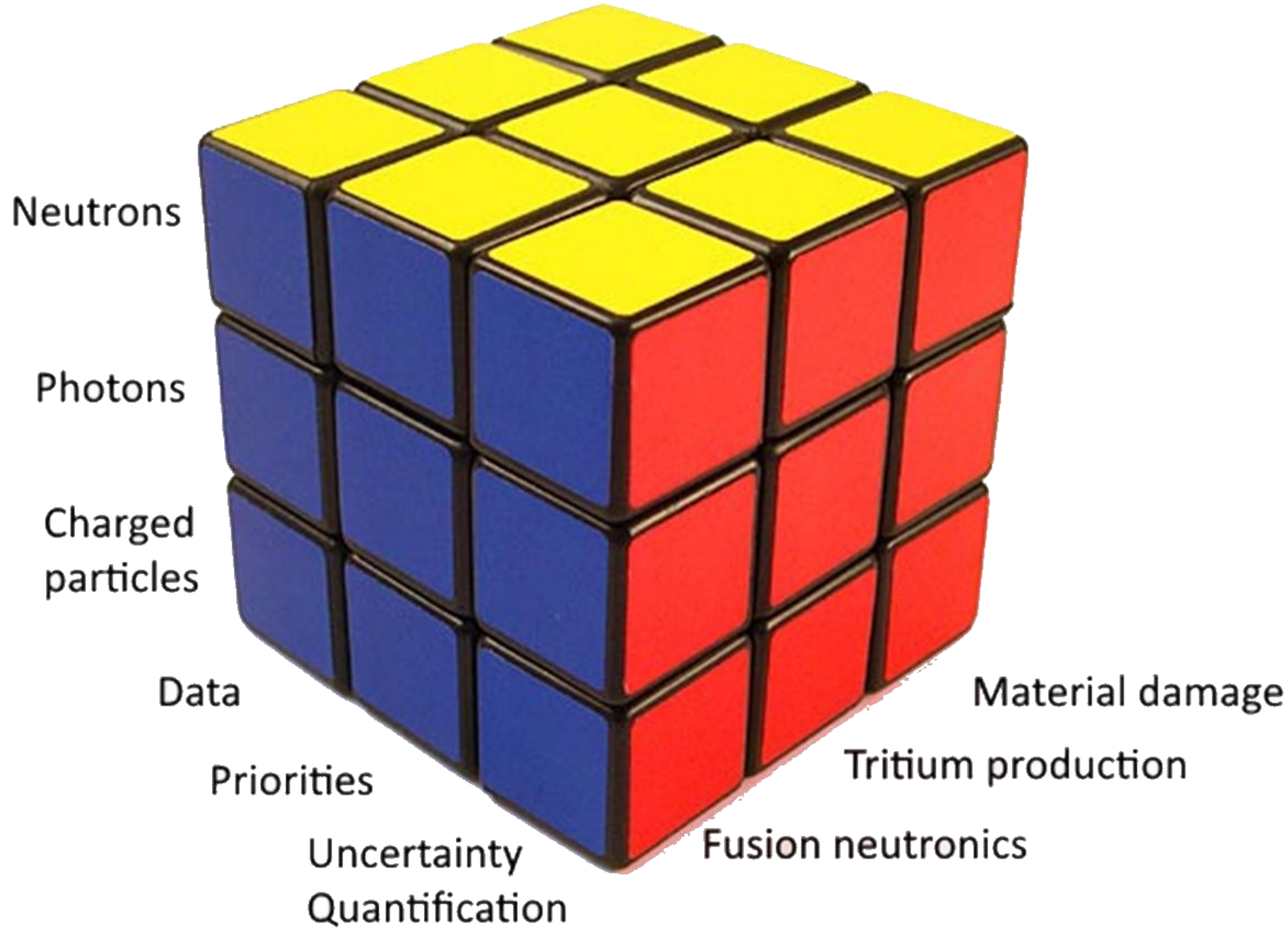
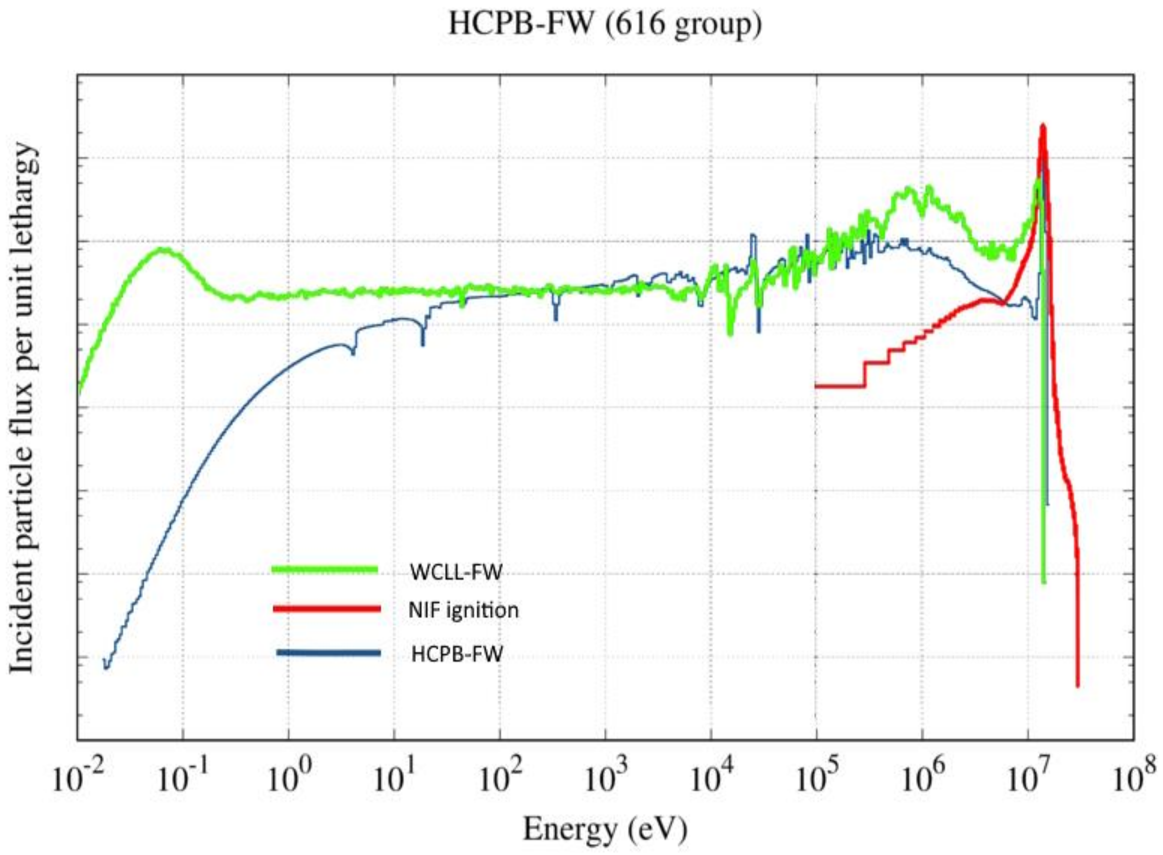
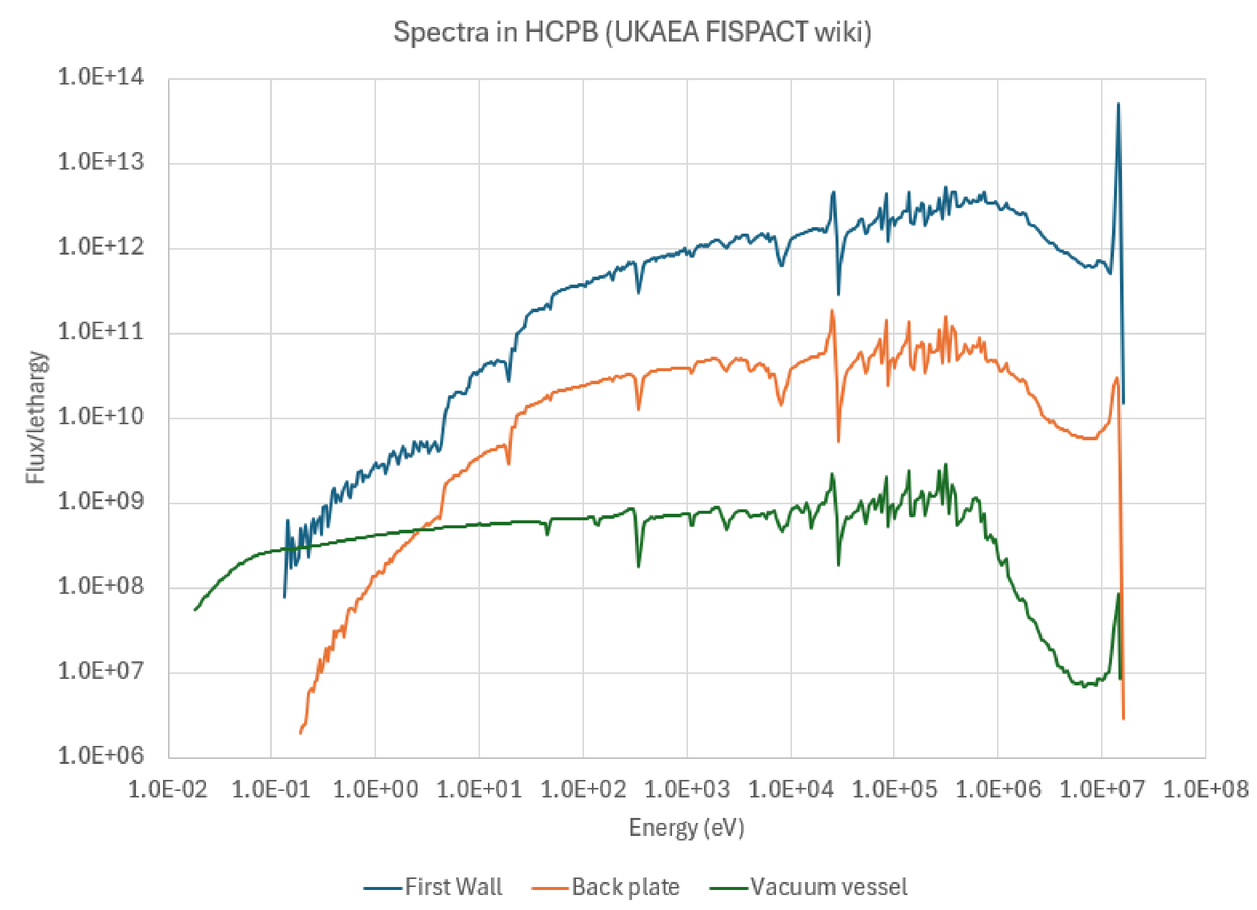
WANDA -24


Neutrons
Photons
Charged particles
Data
Priorities
Uncertainty Quantification
Material damage
Tritium production
Fusion neutronics

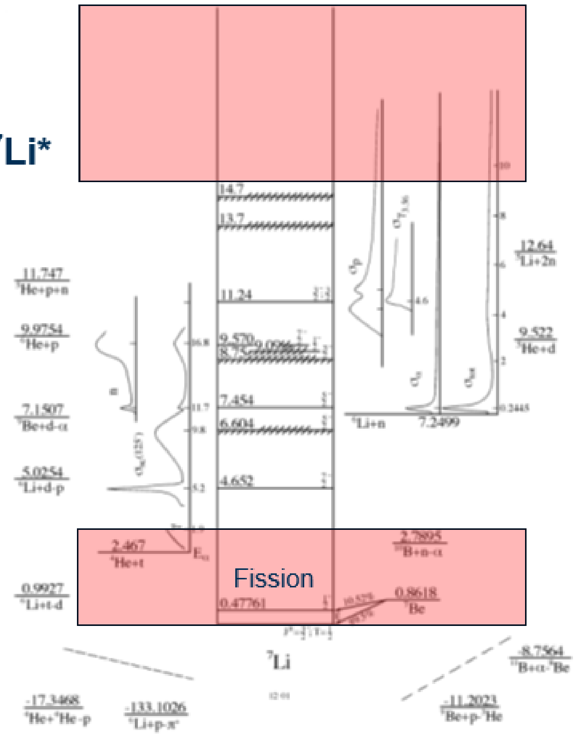
Prioritization of materials and reactions





Fusion source give access to more reaction channels

A=7 energy levels



^{7}Li+n E_{lab}=18 MeV

UK Atomic Energy Authority

Products	Q-value (MeV)	Threshold
^{8}Li + γ	2.032	0
^{7}Li + n	0	0
α + **n + t** (n,n't)	**-2.467**	**2.822**
^{5}He + **t**	**-3.203**	**3.664**
^{4}H + α	-4.070	4.650
^{6}Li + **2n**	-7.251	**8.294**
^{6}He + d	-7.749	8.864
α + **2n** + d	-8.724	**9.980**
^{5}He + **n** + d	-9.460	**10.821**
^{6}He + **n** + p	-9.973	**11.409**
^{7}He + p	-10.384	11.878
α + **3n** + p	-10.949	**12.525**
^{5}He + **2n** + p	-11.684	**13.366**
^{5}Li + **3n**	-12.910	**14.770**

t t out

bold n out

fusion only

12 |

Uncertainty and Evaluation

Recommndation - further fusion relevant experiments

MIT PSFC

Summary

- Uncertainty propagation through fusion workflows is limited due to workflow complexities, nuclear data and availability of computational tools
- Gaps in nuclear data, coupling different codes, and lack of single platform makes S/U analysis challenging in fusion
- For responses with limited and incomplete uncertainty analysis
  - Radiation damage/dpa (cross-section uncertainties N/A)
  - Shutdown dose rates (photo-atomic cross-section uncertainties N/A)
  - Nuclear heating (photo-atomic cross-section & KERMA uncertainties N/A)
  - Randomly sample model parameters (TALYS)
    - Calculate cross-sections from random model parameters (NJOY HEATR/GAMINR)
    - Obtain statistical moments, propagate uncertainties through code

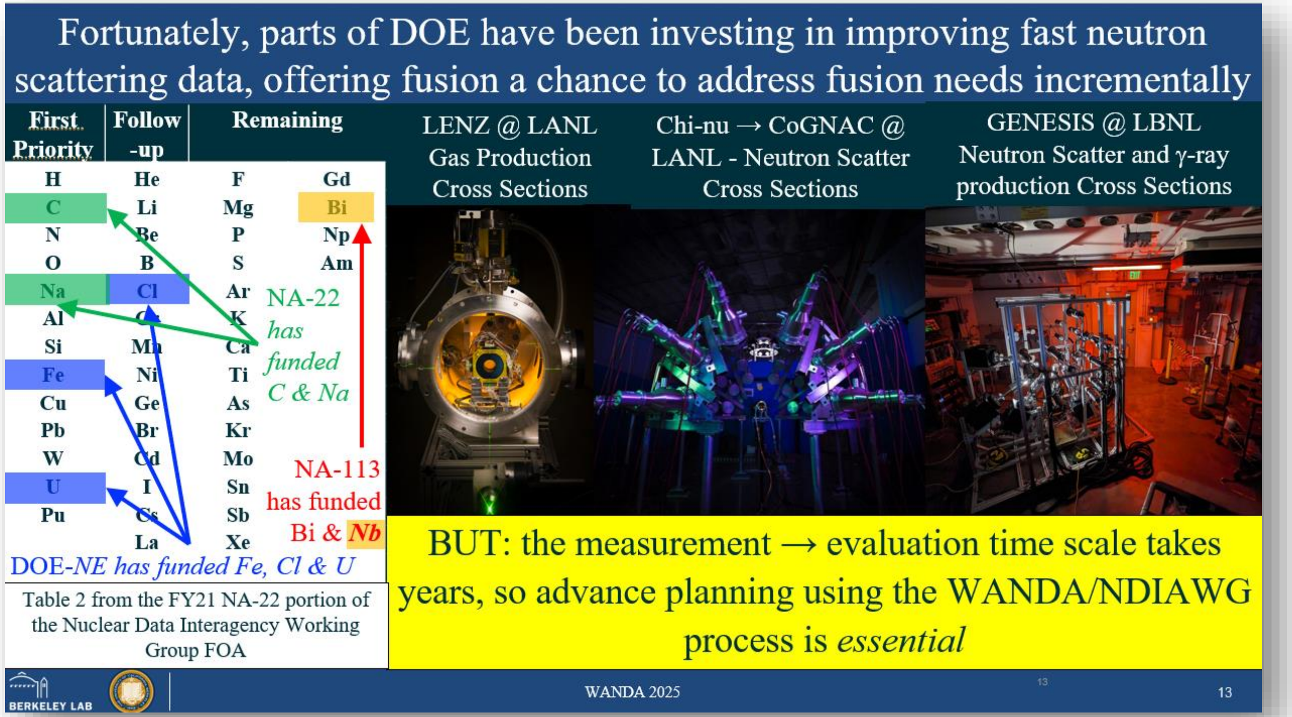
In the absence of a Fusion Prototypical Neutron Source

More data leads to improved AI/ML supporting the exploitation of modern supercomputers for improved

Radiation transport (fusion needs bigger models)

Molecular dynamics, material developments

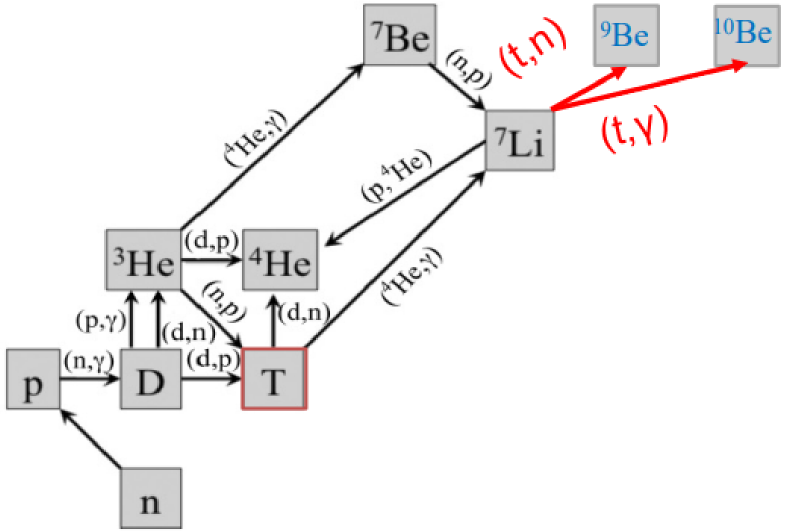
Improve data evaluation (poster)



Cross-cutting benefits for basic science and fusion

Motivation – Big Bang Nucleosynthesis

Tritium-induced nuclear reactions are required to fully understand primordial nucleosynthesis and are investigated as a possible solution to the lithium problem

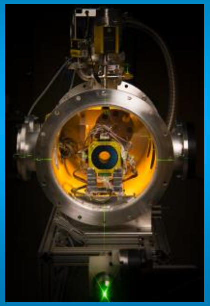


- Current predictions for the abundance of D, ^{3}He, and ^{4}He are consistent with values inferred from astronomical observations.*
  - in opposition, the observed ^{7}Li abundance is three times lower than predicted in current models
- Tritium-induced reactions is one mechanism to explain the depletion of ^{7}Li in the early Universe
  - tritium ^{3}H serves as intermediary storage for neutrons, facilitating the bridge of the mass 5 and mass 8 gaps
  - this feeds the heavier isotopes while generating a high neutron flux if the reaction rates are competitive with inverse ^{7}Li(p,α)^{4}He process*

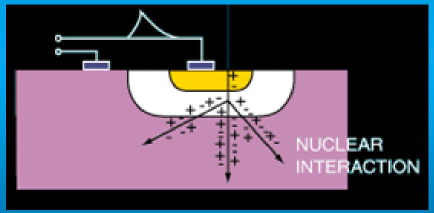
* A. Aprahamian, Nucleosynthesis with Tritium, to be submitted (2025)

Fusion shares data needs with many Applications

National Security

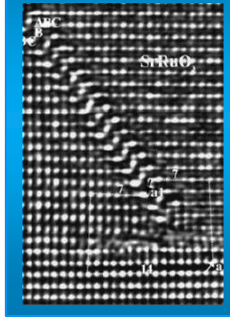



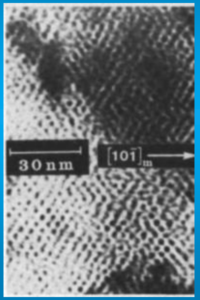
Space Effects/ Exploration



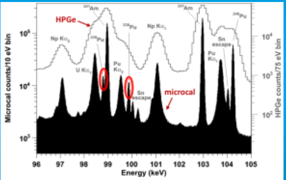
Identify important nuclides → Data Evaluation and UQ → Utilize existing capabilities to field Measurements & Benchmarks → Improved Data-based AI/ML modeling

Nuclear Materials





Nonproliferation/ Safeguards



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Similar Nuclei Are Widely Interesting, but for Different Reactions and Outputs

NA-22 γ-Prod. Interests

1st Pri.	2nd Pri.	Remaining
H	He	F
C	Li	Mg
N	Be	P
O	Cl	S
Na	Cr	Ar
Al	Mn	K
Si	Ni	Ca
Fe	Ge	Ti
Cu	Br	As
Pb	Cd	Kr
W	I	Mo
U	Cs	Sn
Pu	La	Sb
	B	Xe
		Gd
		Bi

- NA-113 interests span neutron transport more broadly
- NA-22 nonproliferation interests include γ-production for active interrogation
- FES interests include tritium breeding, n multiplication, and activation
  - ^{6}Li(n,t), ^{9}Be$(n,2n)$, ^{208}Pb$(n,2n)$
  - Suite of additional $(n,2n)$ and $(n,3n)$ rxns

NA-114 / DOE SC NP evaluation support is fundamental for impact from any new measurement

LA-UR-25-21268

Fusion Activation & Rad. Chem.

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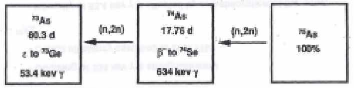

- NA-113, SC FES & NP, NA-114, NA-22
- Space-based physics extend to 50 MeV
- 14 MeV includes variety of (n, xn) rxns

- Keksis (2021) LA-UR-21-23034
- O. N. Jarvis, (1982) EUR–8315–1 EN

Reaction
^{11}B(n,p)^{11}Be
^{14}N(n,2n)^{13}N
^{16}O(n,p)^{16}N
^{51}V(n,a)^{48}Sc
^{65}Cu(n,2n)^{64}Cu
^{55}Mn(n,2n)^{54}Mn
^{59}Co(n,2n)^{58}Co
^{19}F(n,2n)^{18}F
^{63}Cu(n,2n)^{62}Cu
^{89}Y(n,2n)^{88}Y
^{48}Ti(n,d)^{47}Sc
^{45}Sc(n,2n)^{44}Sc
^{90}Zr(n,2n)^{89}Zr
^{52}Cr(n,2n)^{51}Cr
^{47}Ti(n,d)^{46}Sc
^{58}Ni(n,2n)^{57}Ni
^{64}Zn(n,2n)^{63}Zn
^{23}Na(n,2n)^{22}Na
^{90}Zr(n,2n)^{89}Zr
^{35}Cl(n,2n)^{34}Cl
^{46}Ti(n,2n)^{45}Ti
^{39}K(n,2n)^{38}K
^{50}Cr(n,2n)^{49}Cr
^{176}Lu(n,3n)^{174}Lu
^{54}Fe(n,2n)^{53}Fe
^{203}Tl(n,3n)^{201}Tl
^{169}Tm(n,3n)^{167}Tm
^{191}Ir(n,3n)^{189}Ir
^{197}Au(n,3n)^{195}Au

Recommendations

1. Prioritization of materials and reactions

    1.1 This is device dependent because of choice of materials and impact on neutron spectrum

2. Better sharing of information
3. Utilization of existing facilities - value for money
4. AI /ML development
5. Code improvements to make use of improved super-computer architecture

Thank you for your attention