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Benchmarking and Validating Cosmogenic Activation Models

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U.S. Department of ENERGY BATTELLE
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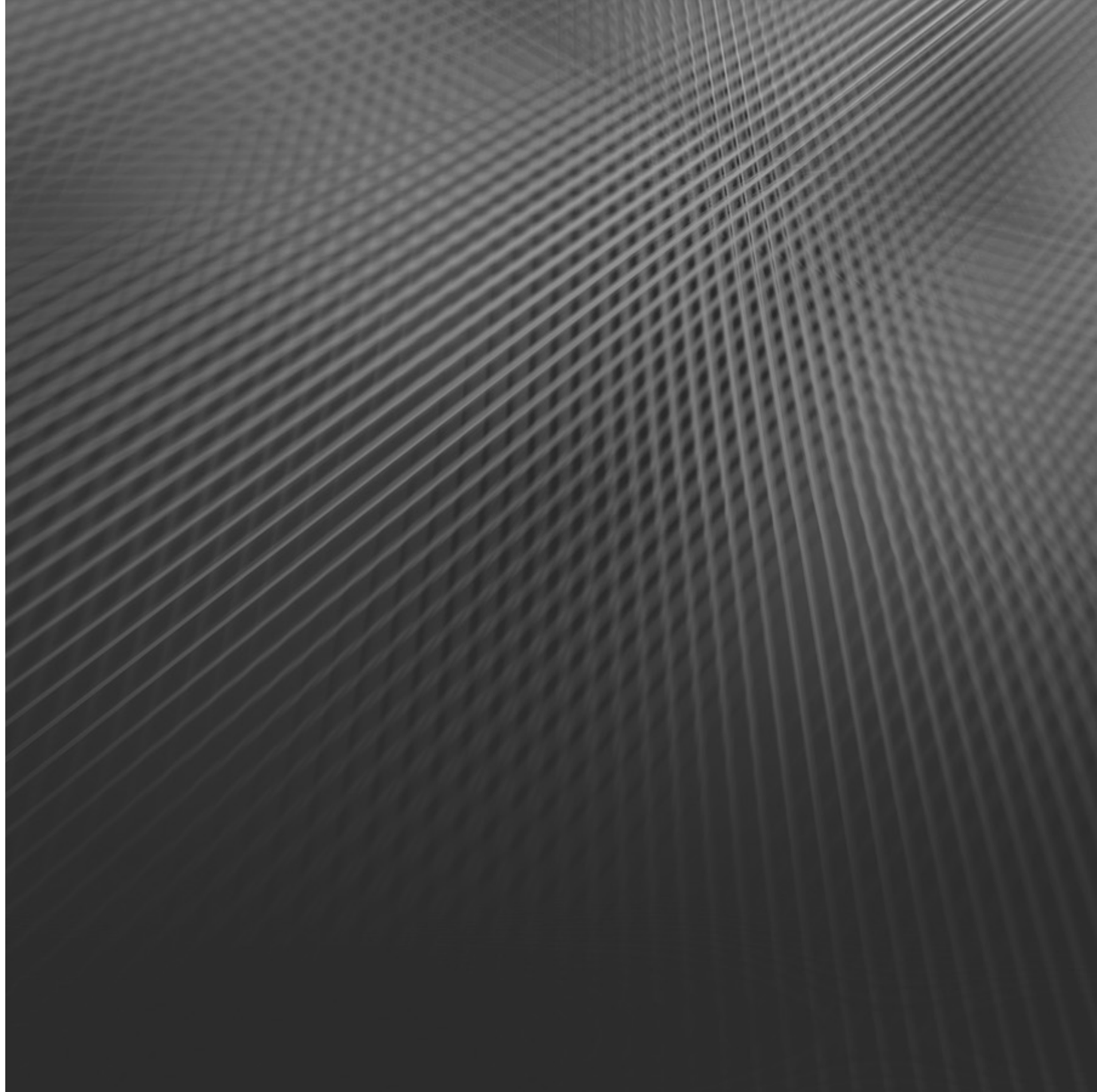
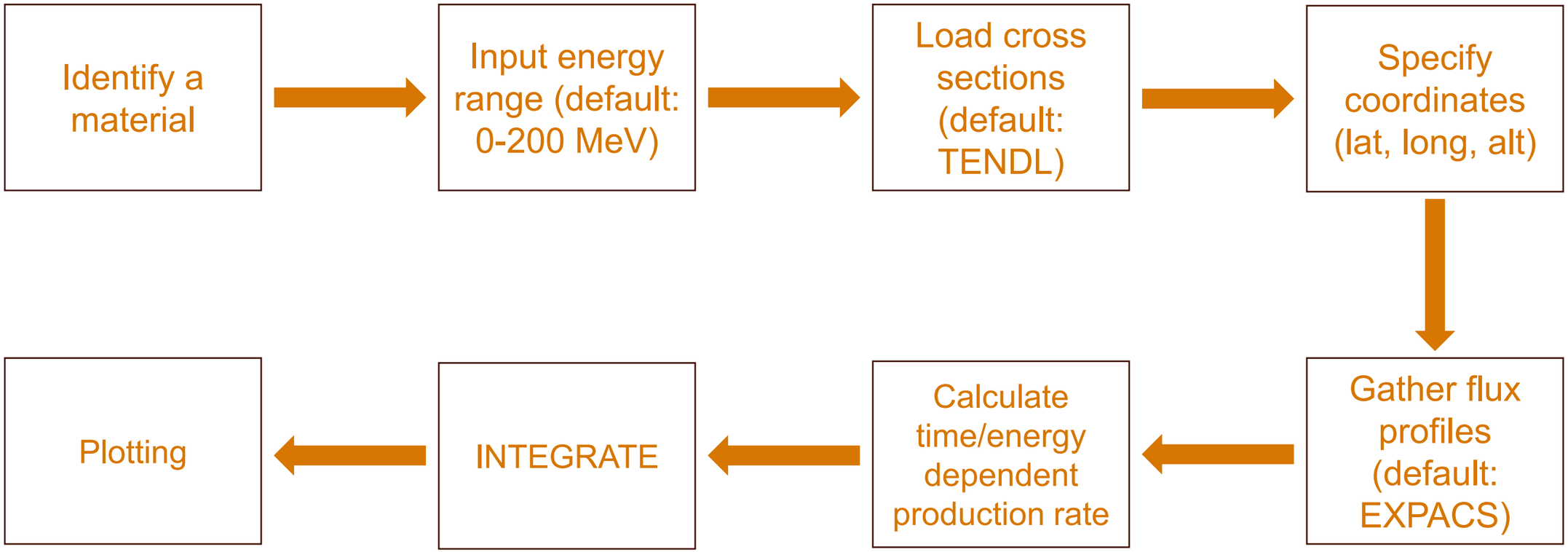


Motivation

- Allow rare event search experiments to carefully plan for primary and secondary cosmic activation

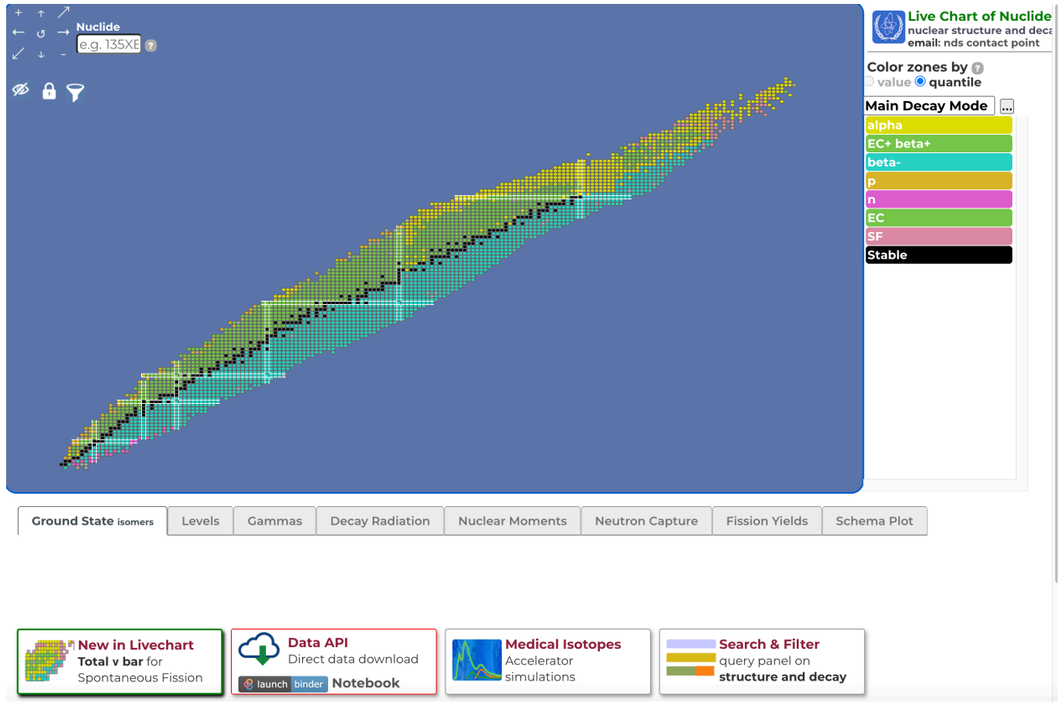
- We will:
  - Optimize witness materials for different exposures (sea level, altitude, and time)
  - Measure cross-sections of possible witness materials if nuclear data gaps exist
  - Create open-source simulation that estimates production rate and activity of isotopes in Earth's atmosphere
  - Benchmark the code
    - Irradiations at LANSCE
    - Low and high-altitude stationary exposures
    - Transcontinental flights
    - Counting to be done at Stanford Underground Research Facility (SURF) and at Pacific Northwest National Laboratory (PNNL) Shallow Underground Lab (SUL)

ACTIVATE: How does it work?

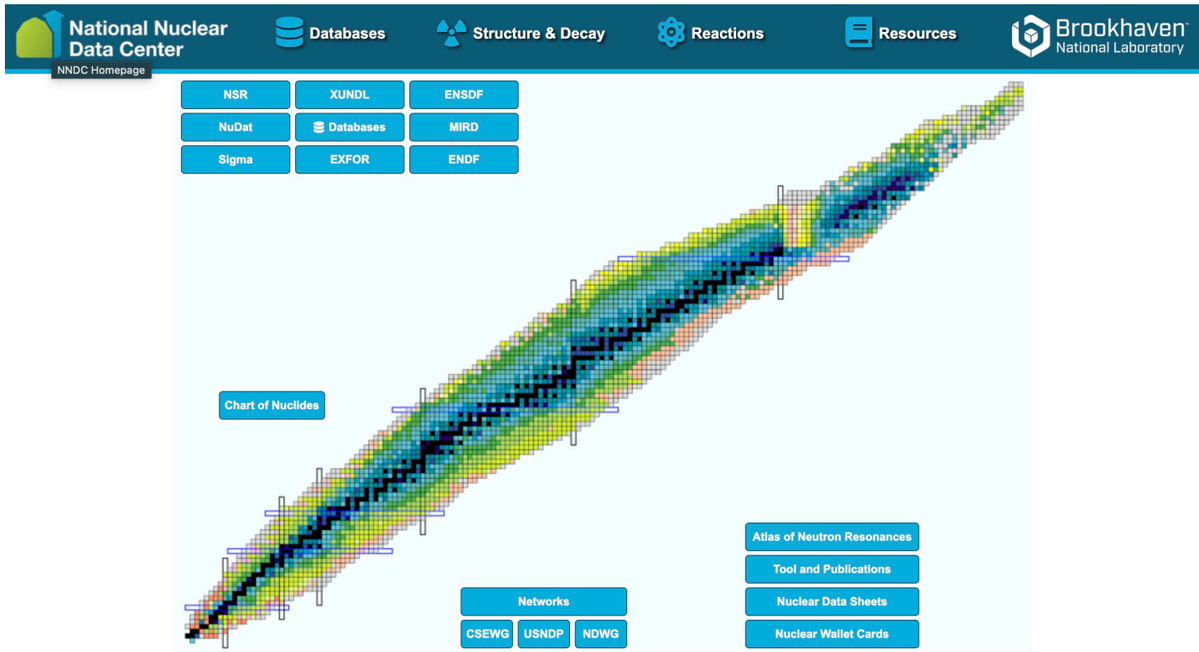


Identifying Witness Material Candidates

IAEA Nuclear Data Services



BNL National Nuclear Data Center



Use existing isotope databases to collect full set of possible isotopes for witness materials

Downloaded all relevant isotope data and saved in dataframe for subsequent work

~ 1600 isotopes

~ 190,000 decay schemes

Identifying Witness Materials

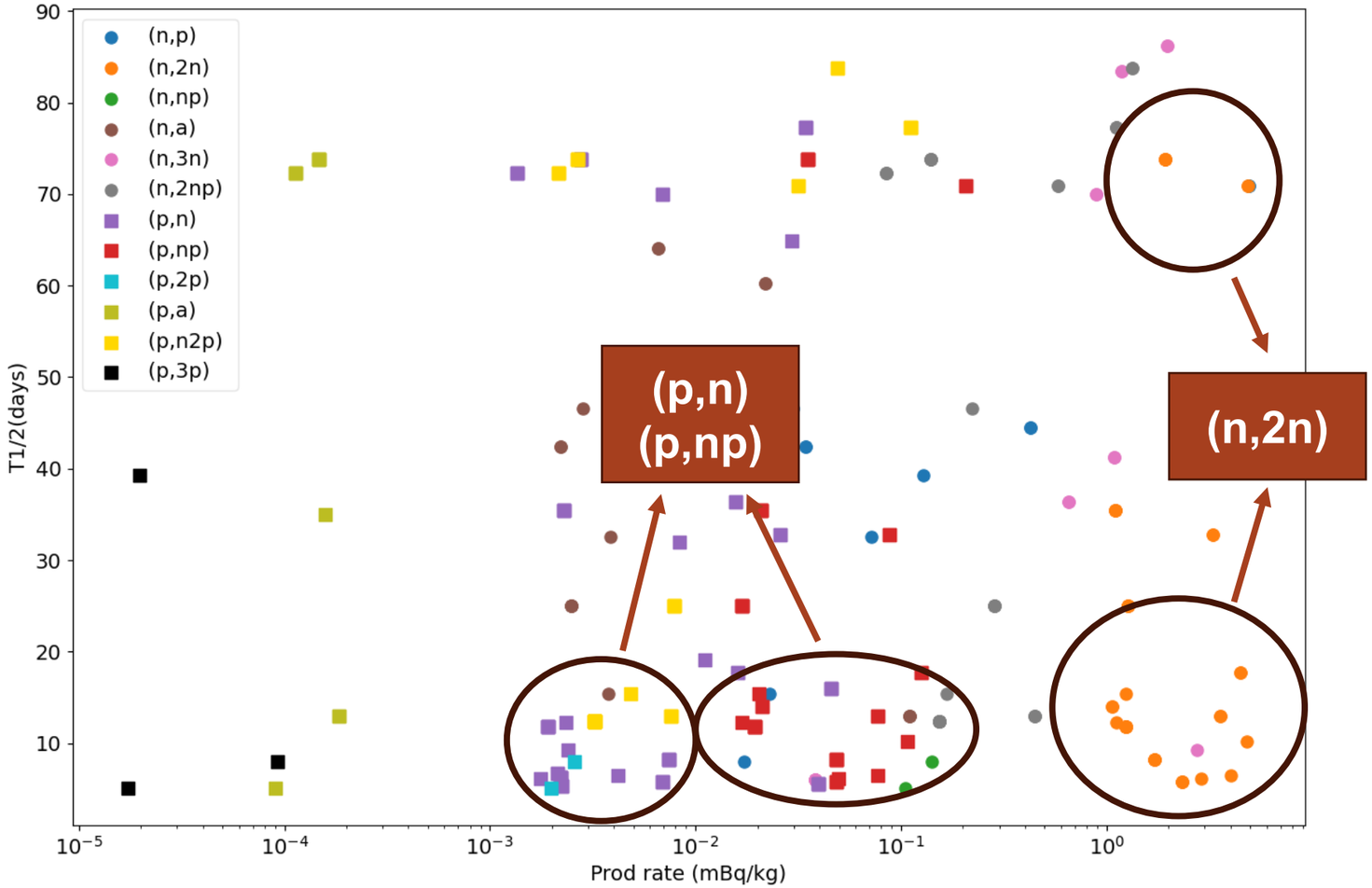
Select radioisotopes with suitable half-lives

Select isotopes with gamma ray transitions above a threshold energy and intensity

For each reaction select target isotopes above a threshold natural abundance

Extract reaction cross-sections from TENDL

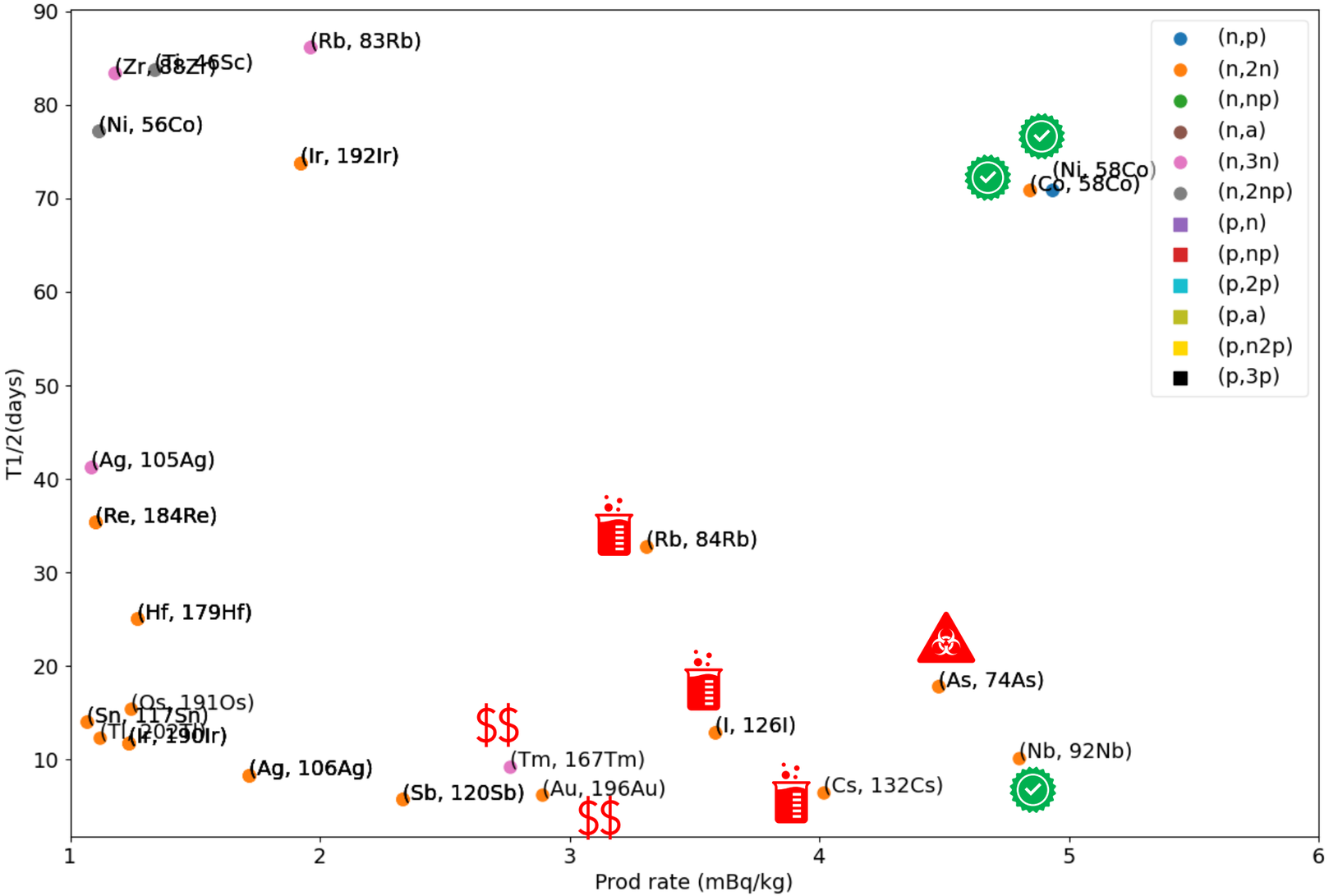
Integrate cross-section with particle flux (EXPACS) to calculate production rates



(n,2n) reactions typically have highest production rates

Proton-induced reactions having lower rates due to the lower flux at sea-level

Candidate Witness Materials



Besides production rates and half-lives, one also needs to consider:

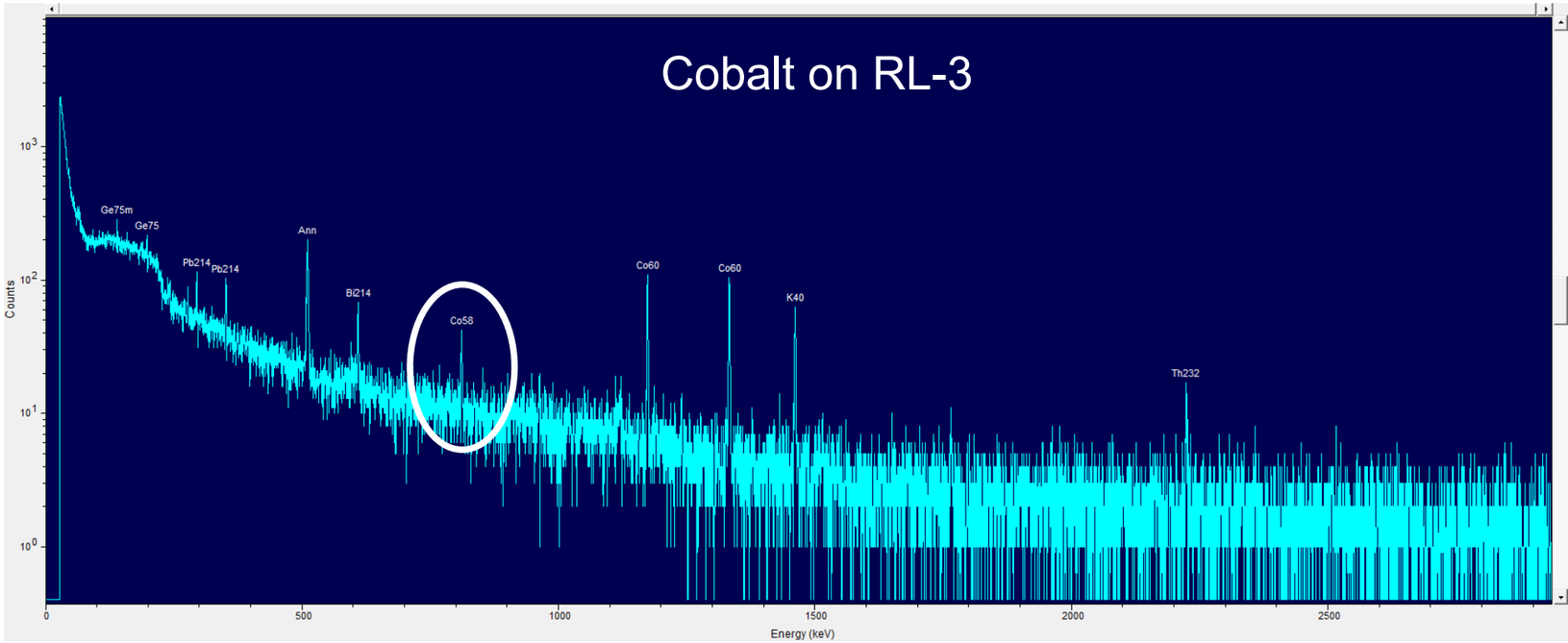
- toxicity
- chemical reactivity
- price

Candidate witness materials:

- Nickel
- Cobalt
- Niobium
- Titanium
- Chromium

Preliminary benchmarking test

- Short exposure of natural nickel and cobalt
- Origin of materials unknown. Not exposed to saturation
- Counted on HPGe detectors in SUL for confirmation
- Measured activity calculated using STAYSL[1]

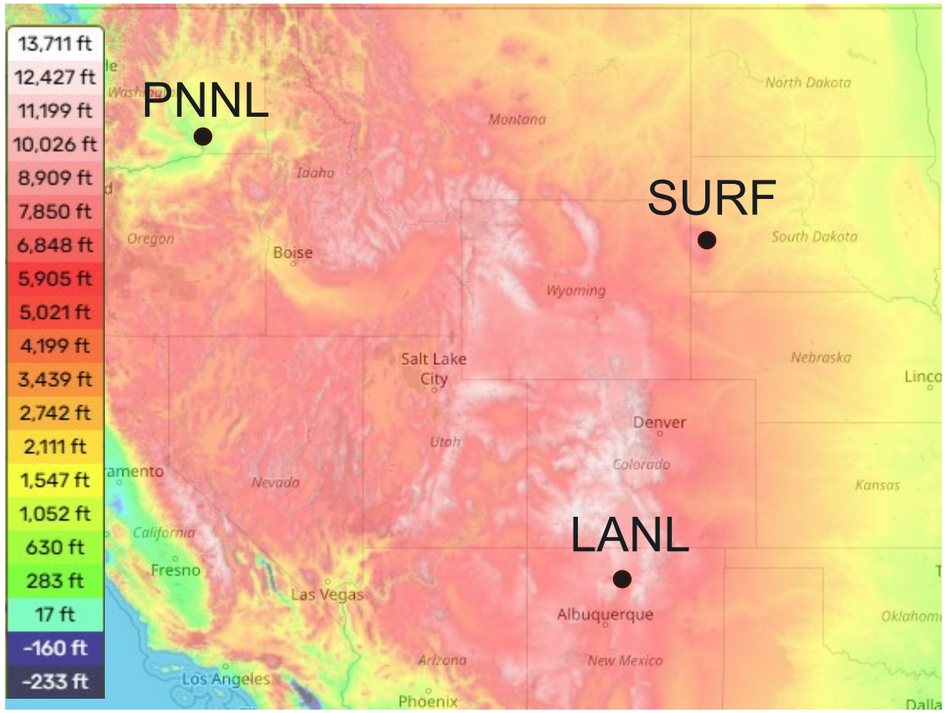


Target	Reactions	Product	PNNL Exposure (Measured [mBq/kg])	ACTIVATE PNNL Saturation [mBq/kg]	ACTIVATE LANL Saturation [mBq/kg]
Nickel	(n,p), (n,2np), (n,3np)	^{58}Co	**4.34 ± 0.46**	**5.39**	29.03
Cobalt	(n,2n), (p,np)	^{58}Co	**6.97 ± 1.25**	**5.47**	29.89

1. Greenwood, Lawrence R., and Christian D. Johnson. *User guide for the STAYSL PNNL suite of software tools*. No. PNNL-22253. Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2013.

Current status of project

- FY2024 LANSCE beam minimal operation
- Currently exposing multiple materials to saturation at PNNL and LANL
  - Co, Ni, Ti, Cr, Nb
  - First step of benchmarking code
  - Higher altitude at LANL means proton reactions become more prevalent
- Will be driven to SURF (Lead, SD)
- GPS tracker to be attached



Source: https://en-us.topographic-map.com/

	Target	Product	Half-life (days)	Time to saturation (days)	PNNL Saturation (mBq/kg)	PNNL -> SURF (mBq/kg)	LANL Saturation (mBq/kg)	LANL-> SURF (mBq/kg)
Neutron reaction	Cobalt	^{58}Co	70.88	354.42	5.63	0.085	30.76	0.13
	Nickel	^{58}Co	70.88	354.42	5.53	0.082	29.97	0.12
	Niobium	^{92m}Nb	10.12	50.60	1.93	0.24	10.60	0.30
Proton reaction	Chromium	^{52}Mn	5.59	27.95	0.055	0.011	0.33	0.016
	Titanium	^{48}V	15.97	79.85	0.062	0.0043	0.34	0.0061

Stationary exposure schedule

- Niobium, chromium, and titanium from LANL are currently being counted at SURF
- Niobium sample exposed at PNNL had large uncertainty during counting. Re-exposure to start soon.
- ^{58}Co production from nickel and cobalt samples won't reach saturation until ~August-September

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Thank you

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