Towards Predicting Instrument Background Beyond Tribal Knowledge

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Background

Background reduction is critical for achieving **high signal-to-noise ratios** in neutron scattering instruments.
However, mitigation strategies have historically relied on **empirical practices and accumulated experience**, rather than on systematic, quantitative analysis.

Challenge

Background noise arises from **multiple interacting sources** associated with shielding, structural components, and the experimental environment, making its characterisation particularly challenging.

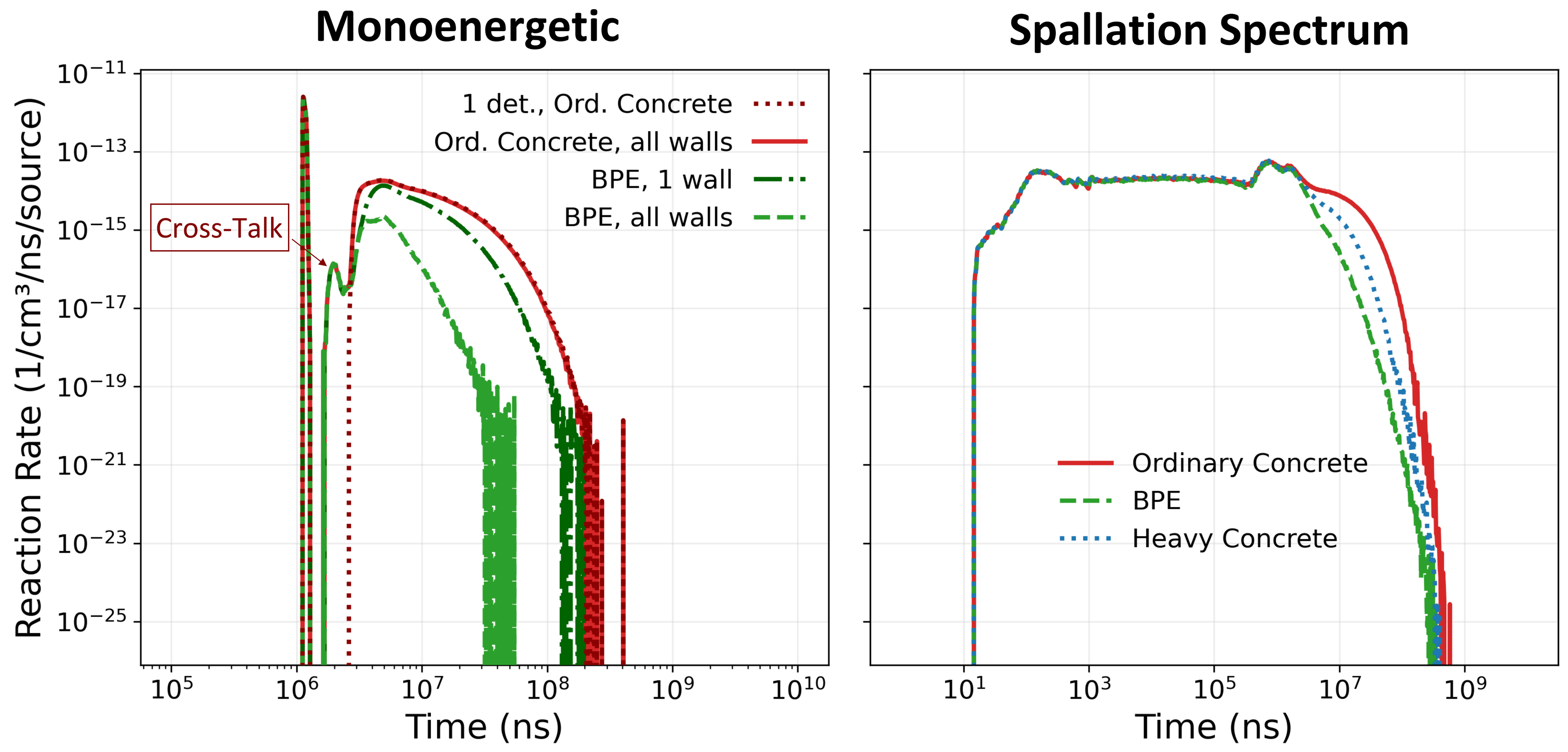
This Work

We present initial steps towards a **rigorous and reproducible framework** for background analysis and engineering.
A simplified instrument **cave** is used as a **controlled test case** to:

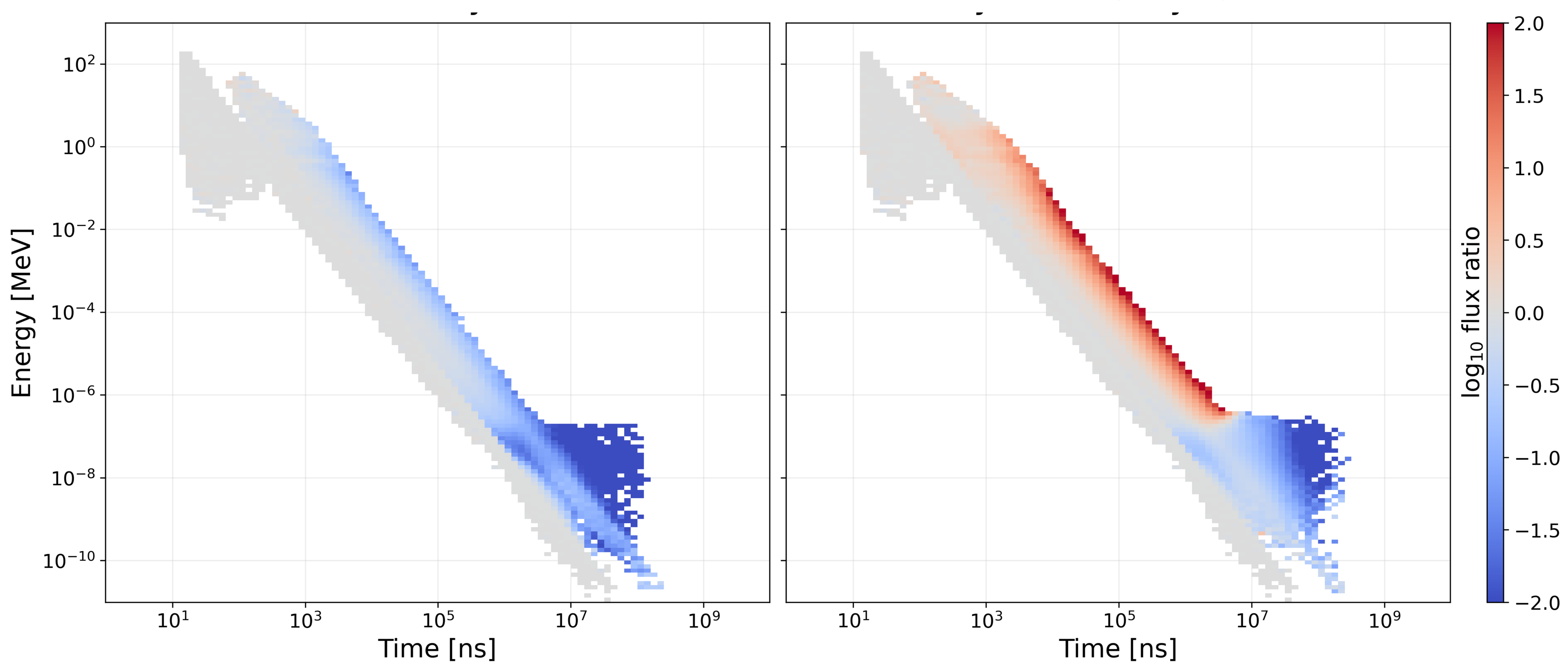
- isolate fundamental background mechanisms
- investigate shielding configurations and material choices
- assess commonly used design concepts using monoenergetic and broad neutron spectra

Materials investigation

Detector Response vs Time



Flux ratio in time–energy
(Spallation Spectrum)



Key Takeaways

- Simulations reproduce **expected physics across time** and **energy scales**
- Background can be **systematically decomposed** using a controlled geometry
- Instrument performance reflects **trade-offs between competing physical processes**
- No universal solution → **mechanism-specific optimisation is required**

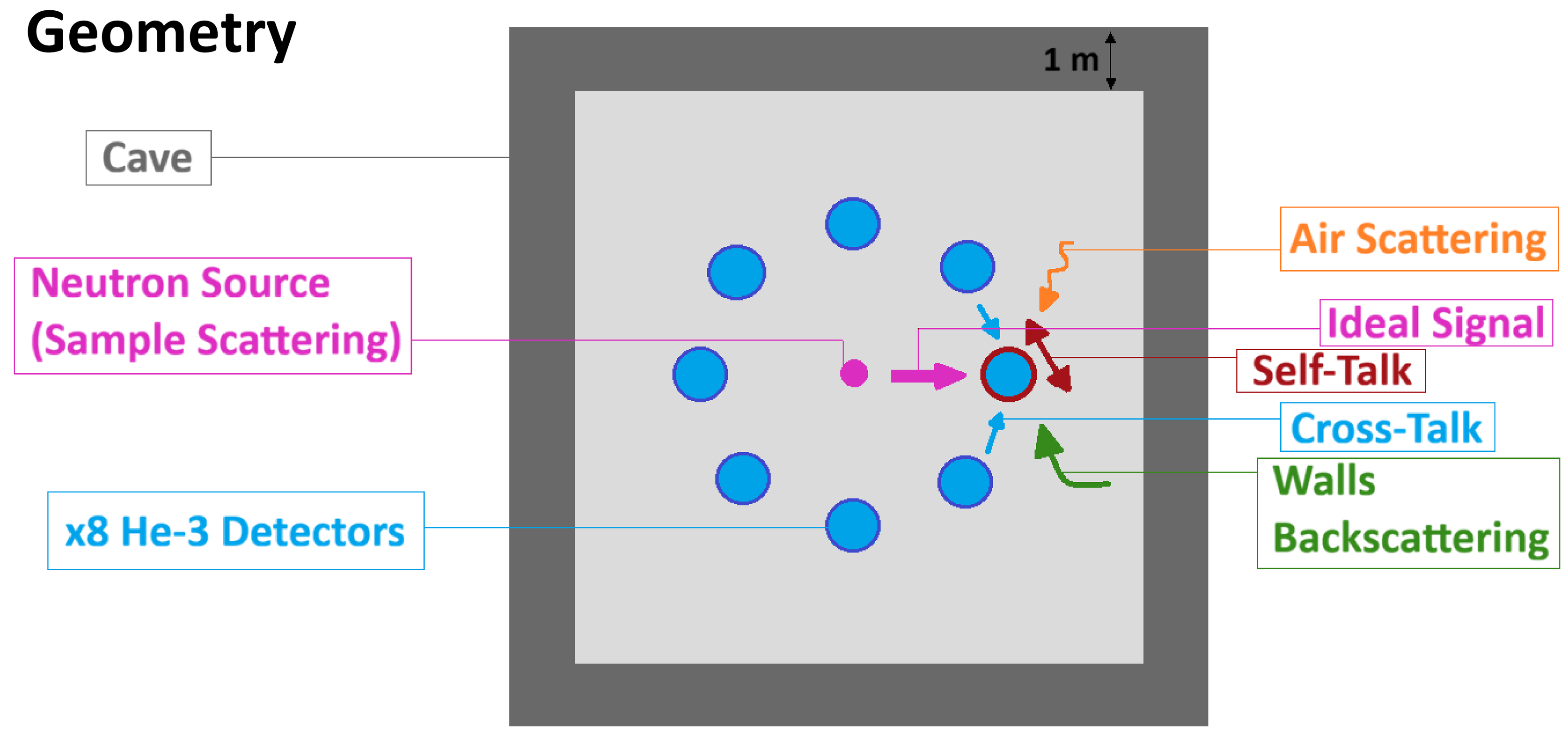
These results provide a pathway towards systematic quantification of background mechanisms.

Future work

- Extend simulations to **instrument-specific geometries and beamline components**
- Identify **dominant background sources** for selected ESS instruments
- Perform **targeted experimental validation**
- Develop **quantitative, transferable background mitigation guidelines**

Controlled Test Case Design

Geometry



Neutron Source

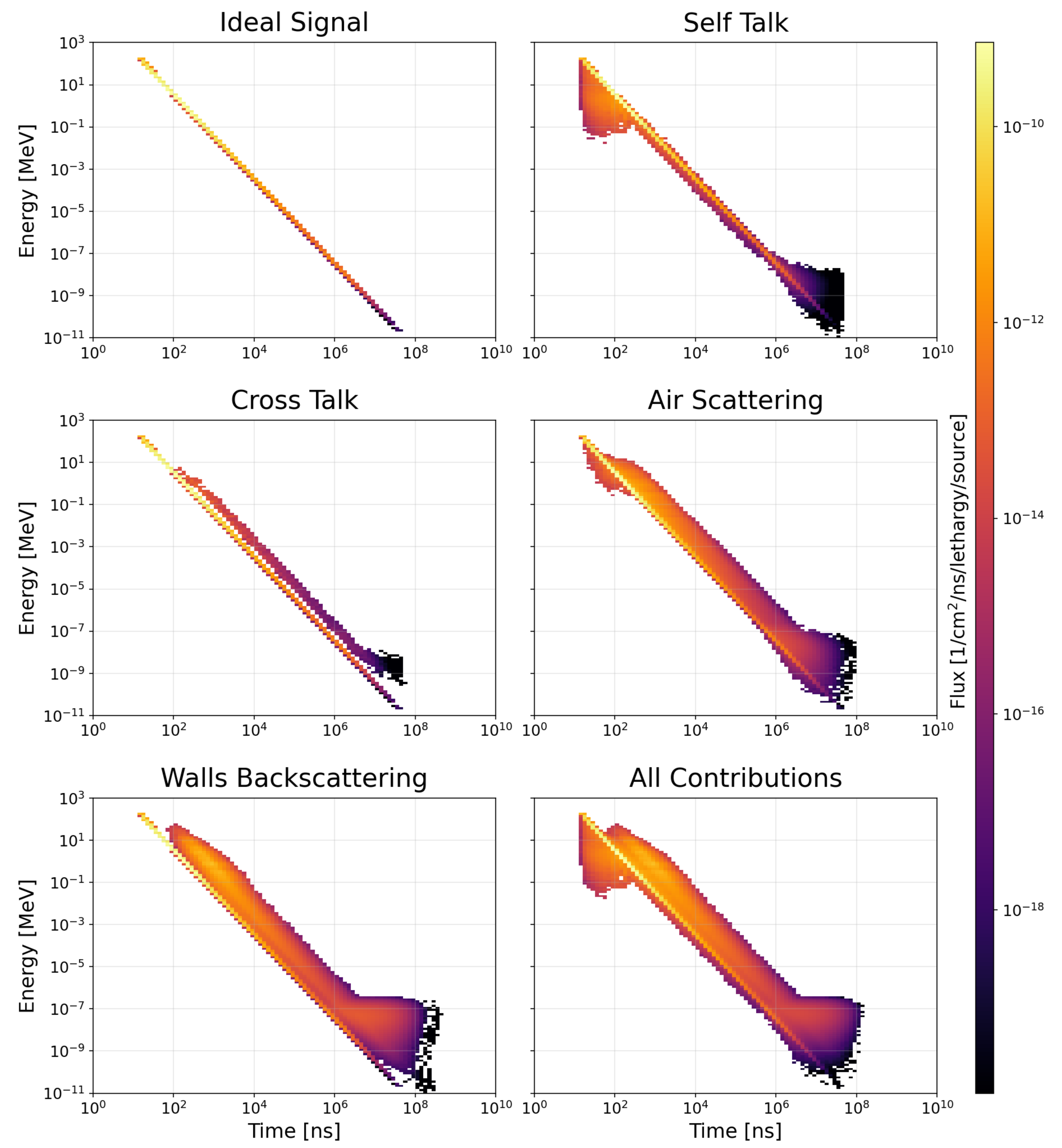
Type	Energy range
Monoenergetic	25 meV
Typical spallation spectrum	up to few hundreds MeV

Shielding configurations

Cave material	Expected Dominant Effect
Ordinary concrete	Strong moderation → **large thermal return flux**
Borated PE layer on **all walls**	**Strong suppression of thermal return** via absorption after moderation
Borated PE layer on **one wall only**	**Directional** suppression of thermal return
Heavy concrete (magnetite)	**Decrease** of **thermal** return, **increase** of **epithermal/fast** return flux

Background subdivision

Time–energy signatures of background components
(Spallation Spectrum)



Each mechanism occupies a distinct region in time–energy space, reflecting its underlying transport physics.

Background contribution relative to signal
(Spallation Spectrum)

Time-dependent contributions determine when each mechanism dominates over signal.