# Neutronics Challenges for spallation facilities

Steven Lilley[1],

1, STFC Rutherford Appleton Laboratory

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Steven.Lilley@stfc.ac.uk

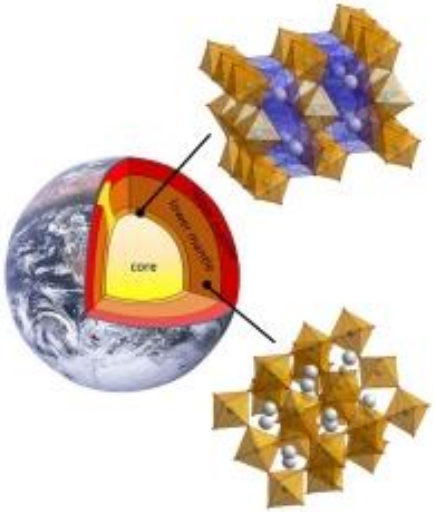
Science & Technology Facilities Council

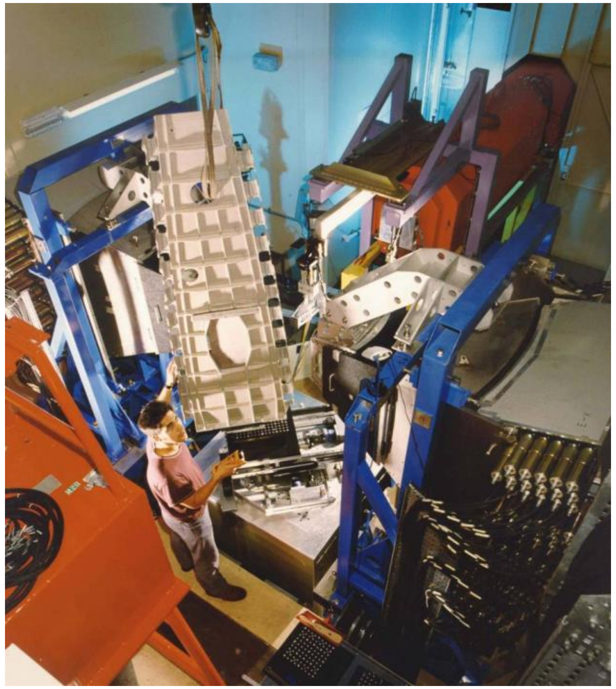
**Outline**

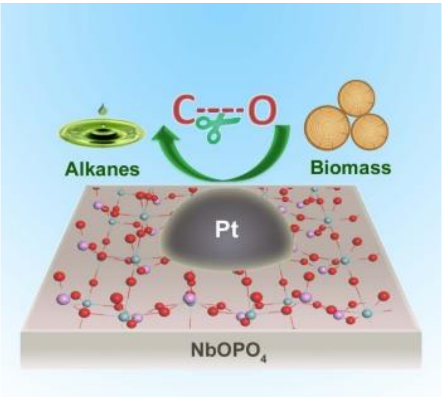
- Neutron Science
- Overview of spallation facilities
- Spallation physics
- Neutronics analysis
- Simulation challenges

# Neutron Science

Used for basic science
- Crystal structure
- Material imaging
- Disordered materials
- Biology
- Chemistry
- Magnetism
- Engineering Analysis
- Historical artefacts



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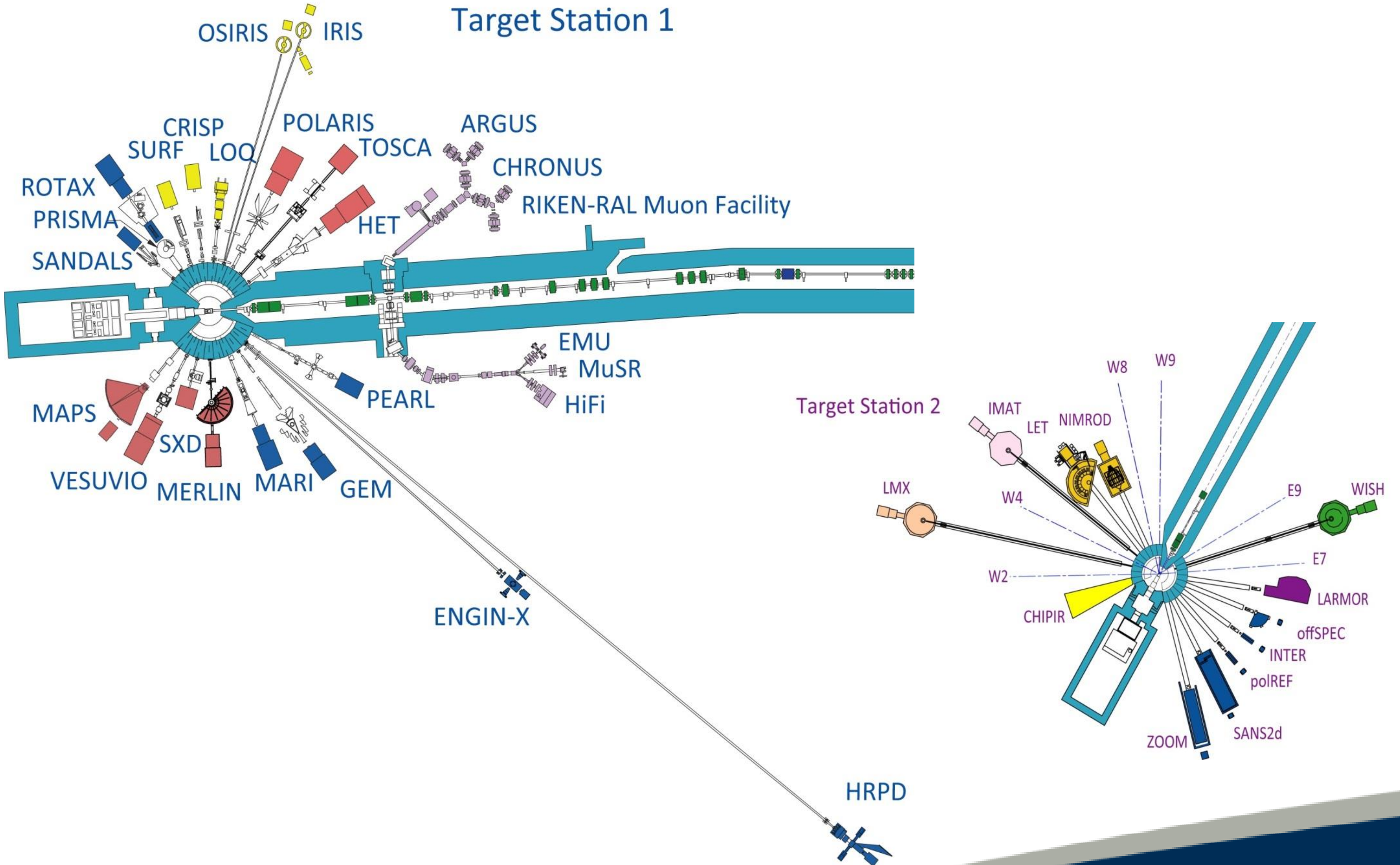


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# Spallation

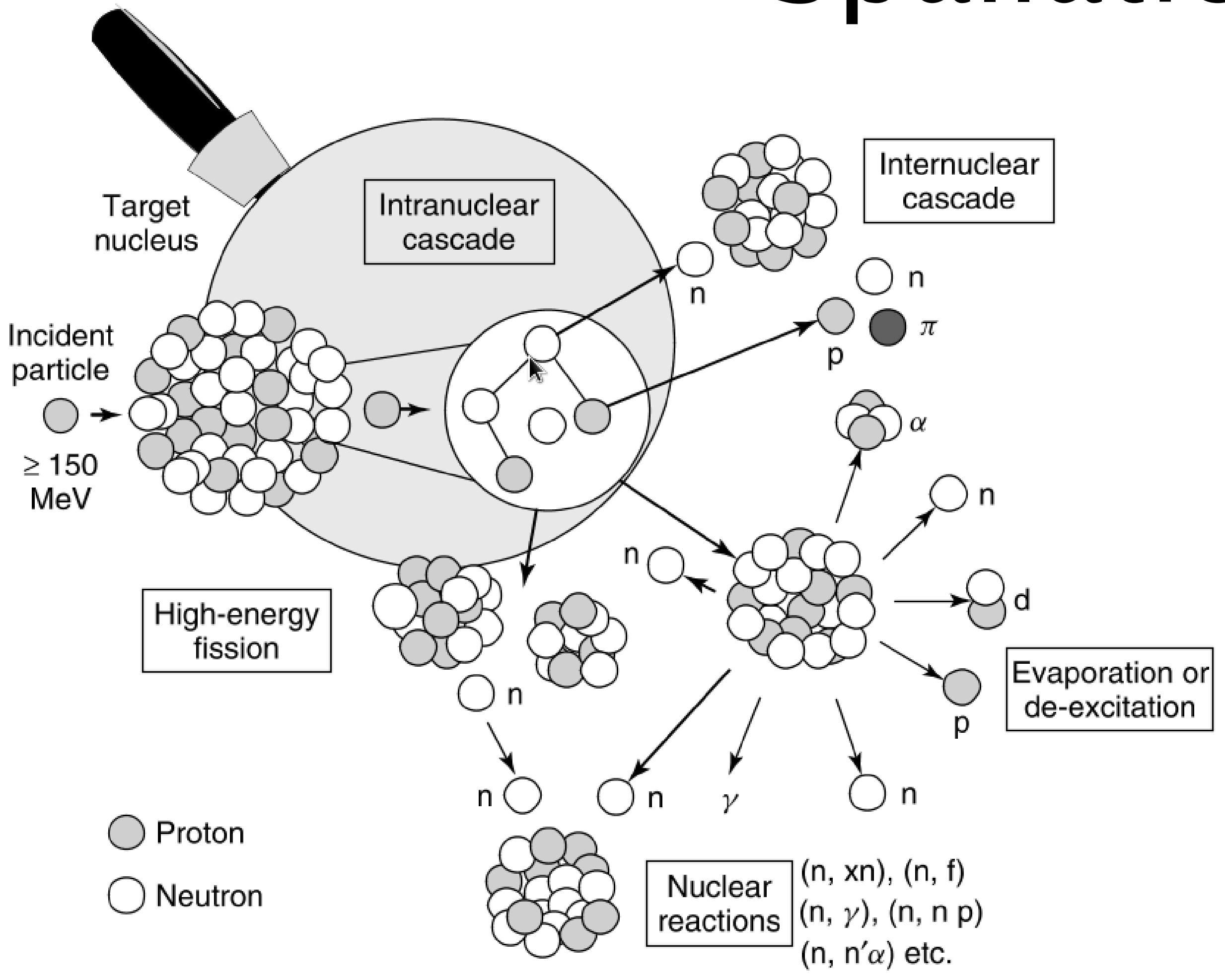



**Fig. 1.12** The principal scheme of spallation.

Filges, D. & Goldenbaum, *Handbook of Spallation Research*, Wiley, 2010

Typically 20-30 neutrons per proton at 1GeV

Depends on the material all high Z

- Tungsten
- Lead,
- Mercury
- Uranium

# Neutron energy Distribution

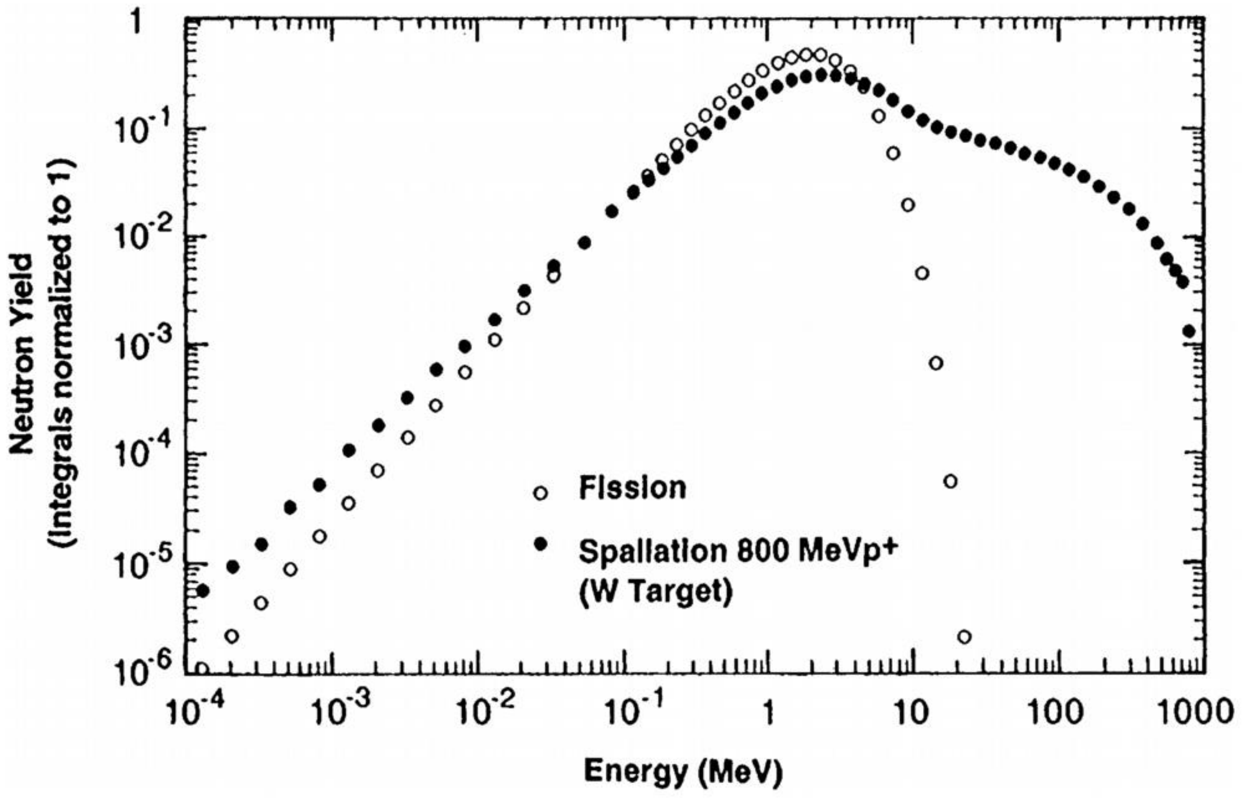



Fig. 3. Calculated neutron spectra for fission and for spallation in a tungsten target [1].

Bauer, NIMA 463 (2001) 505–543

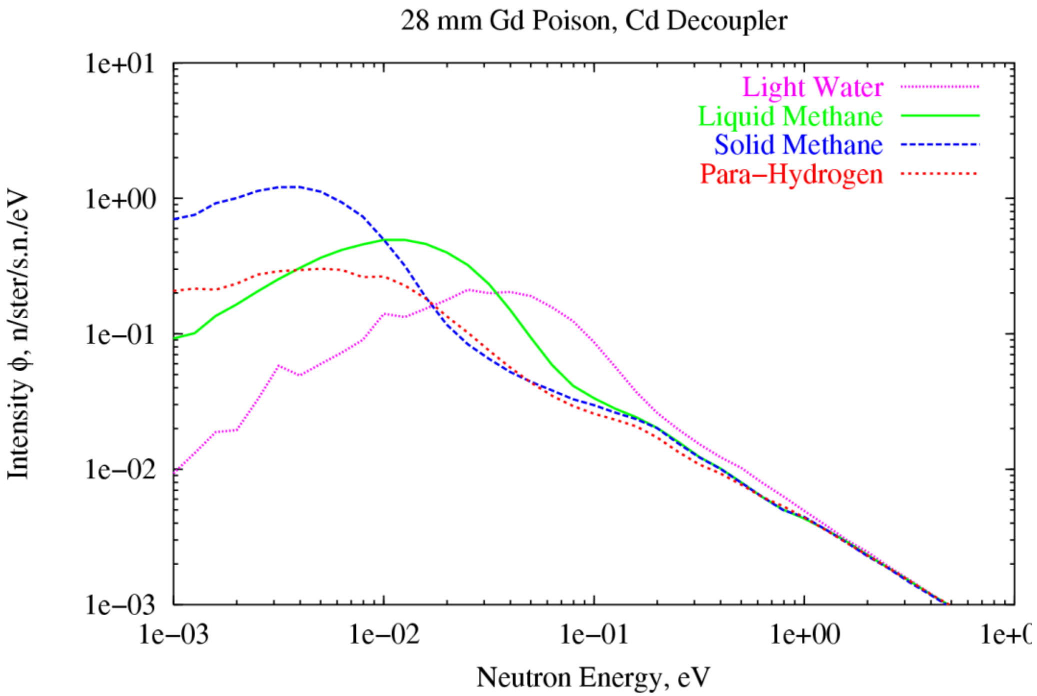
Majority of neutrons are at high energy

But neutron scattering, diffraction and spectroscopy experiments need them at 0.1meV to 10eV range

Need to slow down neutrons to useful energy, but minimise the effect on the time structure needed for time of flight

- Typically use
  - Liquid Methane (122k)
  - Solid Methane
  - Liquid Hydrogen (para-H) (25k)
  - Water

Also need poisons, reflectors, decouplers and premoderators to help keep time structure / flux

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# Nuclear analysis at Spallation facilities

Nuclear analysis provides:-

- Neutron flux and energy/time profile for instruments
- Target heating, damage, He production
- Moderator design
- Activation calculations
- Shielding design
- Detector Design
- Instrument Backgrounds
- Instrument performance

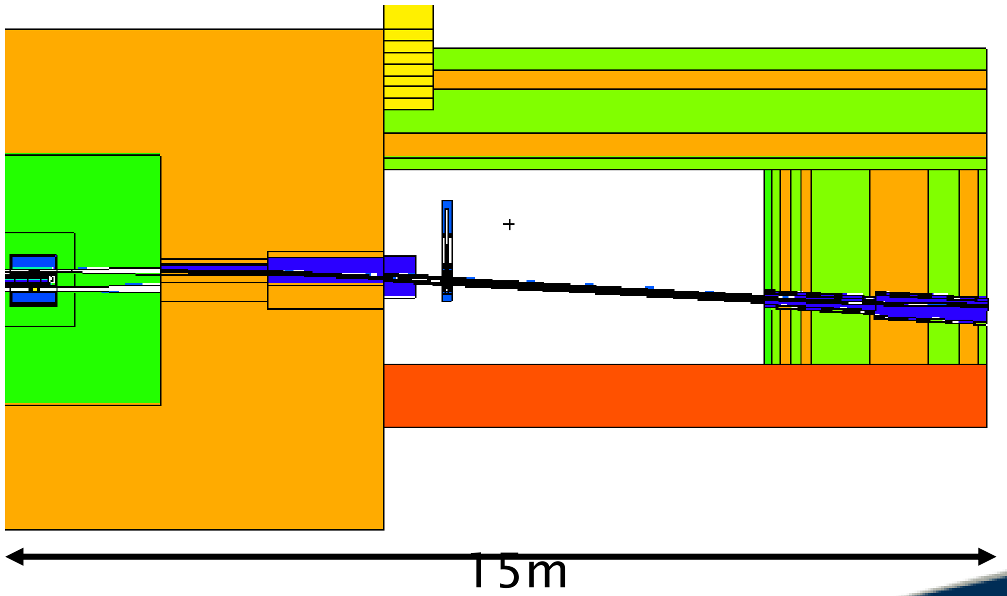
Spallation Neutronics is all about optimising the number of useful neutrons and operating safely

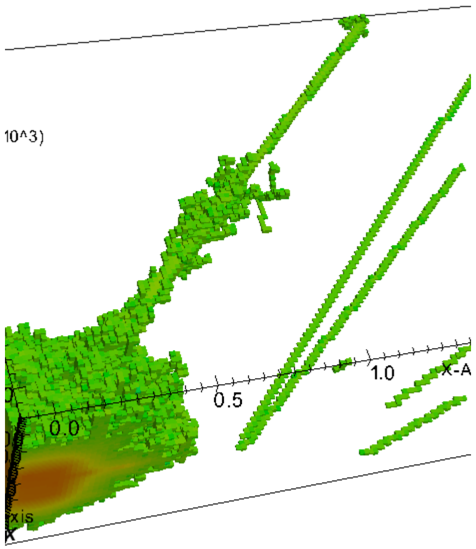
# Challenges for spallation nuclear analysis

- 12 orders of magnitude in energy range – need both high energy physics models and thermal scattering kernels
- Large facilities – challenging geometry – over 150m beam lines @ ESS – potentially penetrations are less than 10cm diameter
- Multi-physics – moderators including long term radiochemistry
- Time dependant – most instruments work on time of flight principle
- Backgrounds are important – many contributions
- Calculation of activation & damage in high power targets

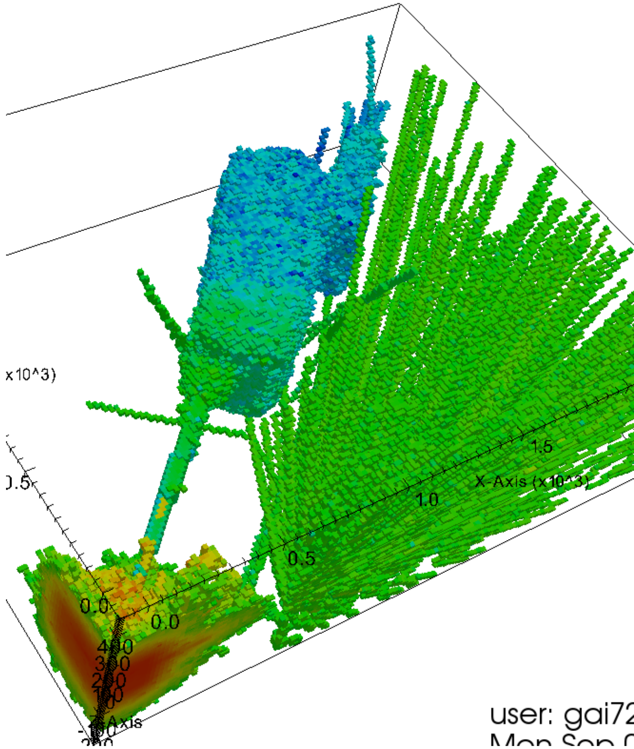
# Challenges - geometry

Very long thin streaming channels, lots of thick heavy shielding
Analog simulations cannot simulate in reasonable time
Variance reduction methods needed but still challenged to be efficient and scale well
Very large aspect ratio – up to150m long 10cm wide beam tubes.



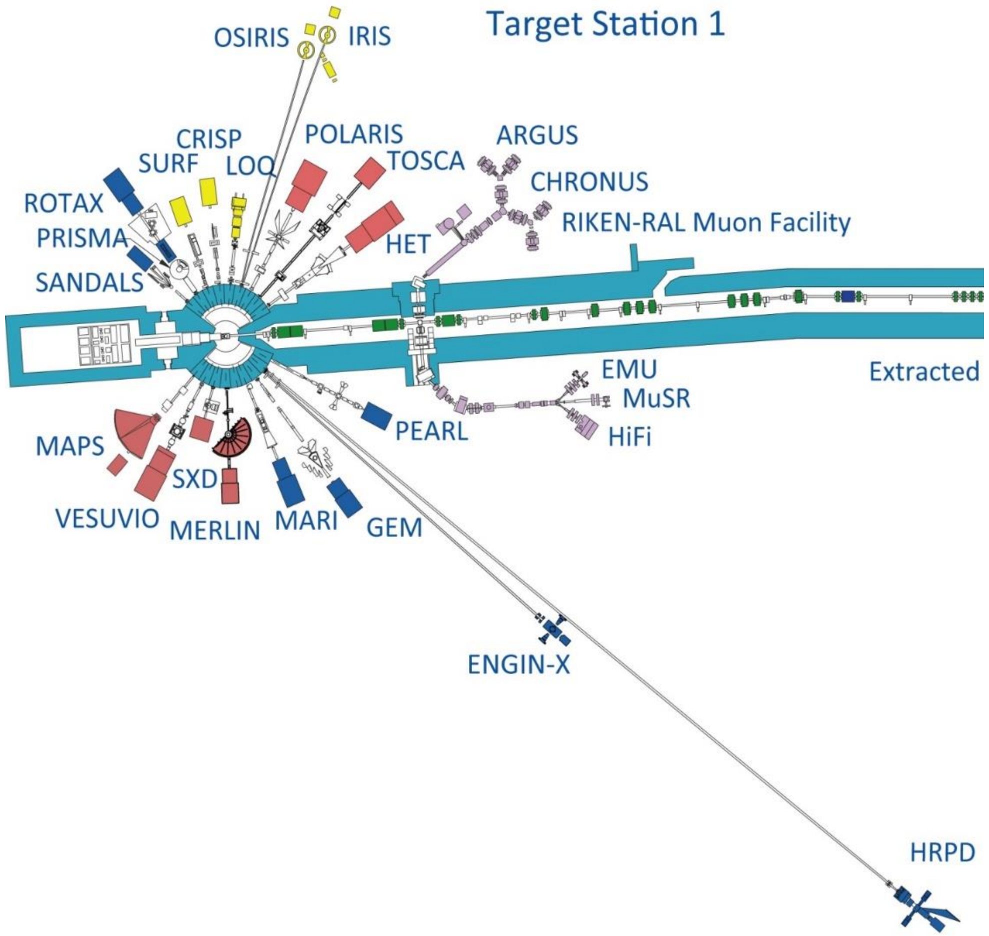




analog




ADVANTG

# Challenges - geometry

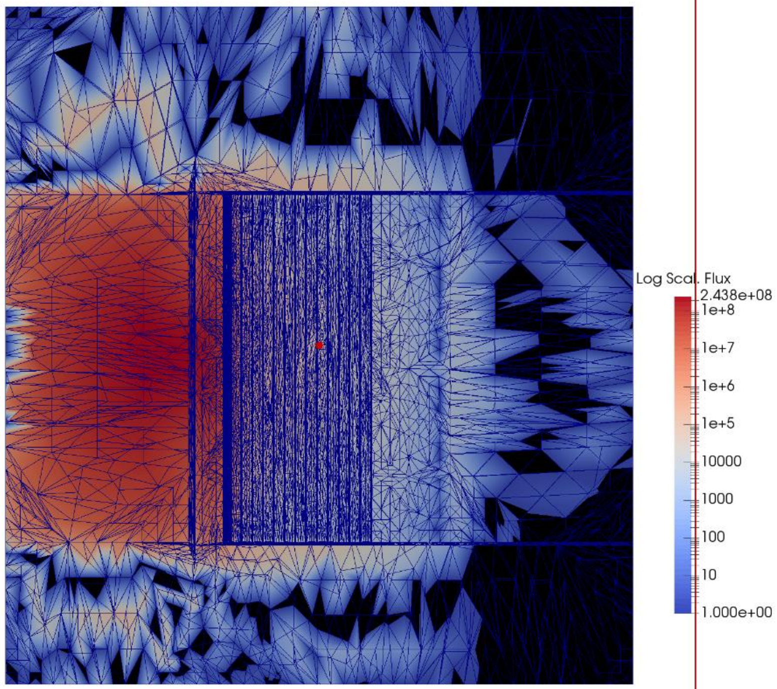



- Traditional deterministic code e.g. Denovo/ADVANTG used to generate weight windows
- Quadrature set really matters, to get even vague answers need to align with the beam line.
- Some beam lines bend in multiple directions

- We hope space/angular adaptively will help

# Recent Boltzmann work

- Using DENOVO/ADVANTG for variance reduction – generating new quadrature sets, currently looking at a new high energy library as well
- Testing FETCH for relevant geometries
- Adding more nuclear data to FETCH
- Benchmarking FETCH – SINBAD




ASPIS-FE88, SINBAD Winfrith benchmark, FETCH2 Energy group 47

# Summary

- Spallation neutron sources are very efficient at producing neutrons for neutron science experiments
- They are complex, large scale facilities with many interesting physics and engineering challenges
- Nuclear analysis is an essential part of the design and improvement of these facilities
- There are many challenges associated with performing nuclear analysis for spallation facilities
- Many interesting challenges and problems to solve but we do a good job for most target and moderator problems using Monte Carlo.