Development fast generic activation code for high-complexity models

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Fundamental Problem

We wish to determine activation dose on complex beamlines

Considerations:

- Beamlines on neutron sources are built with enormous numbers of components.
- Flux values have become so high that the volume of activation has extended greatly
- Long pulse instruments have far more, bigger and closer choppers than most other instruments

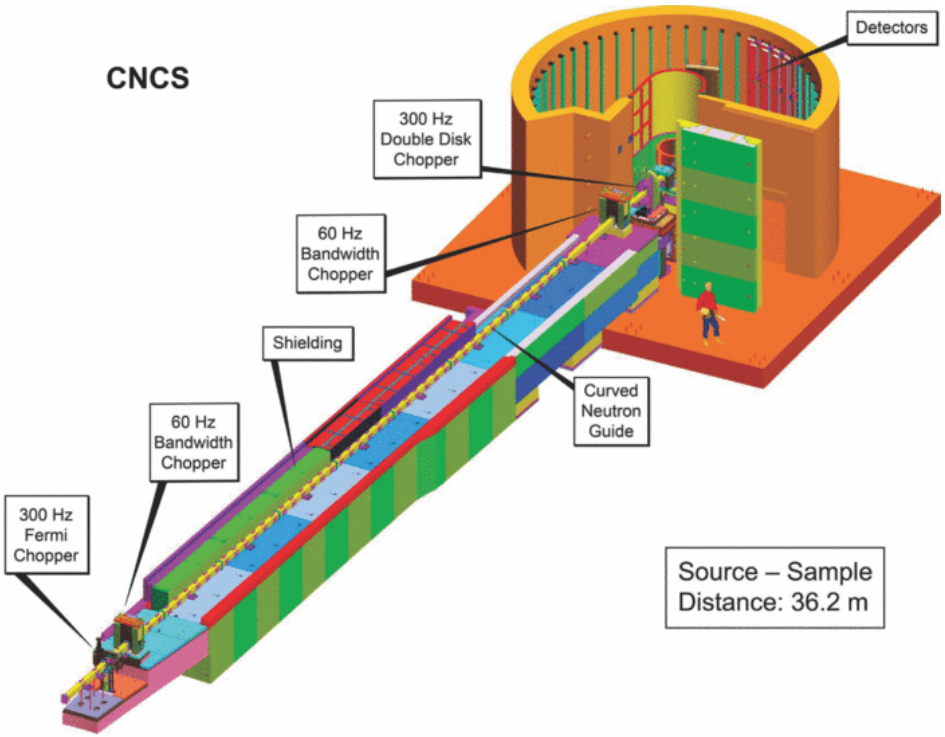
This translates into:

1. Highly complex environment
2. Huge number of cell items

Current tooling is insufficiently scalable to the required complexity

Requirements

- Geometry Modeling System – This allows large component to be dropped in and connected.
- Fast **Stable** Variance reduction system
- Activation method that can be carried out with macroscopic values

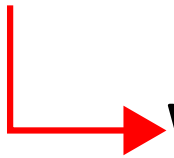


- Any step longer than 2 hours is a failure [including simulation]

Calculation Process

CombLayer *C++ code (350k lines)*

- Fully interchangable/connectable component geometry
- Variable driven
- Variance reduction
- Open source



Writes MCNP/Fluka/PHITS input decks

Used by

- Delft/Bilbau/Culham/ITER/RAL/Aldermaston

This allows the rapid development of complete semi-engineering models.

https://github.com/SAnsell/CombLayer

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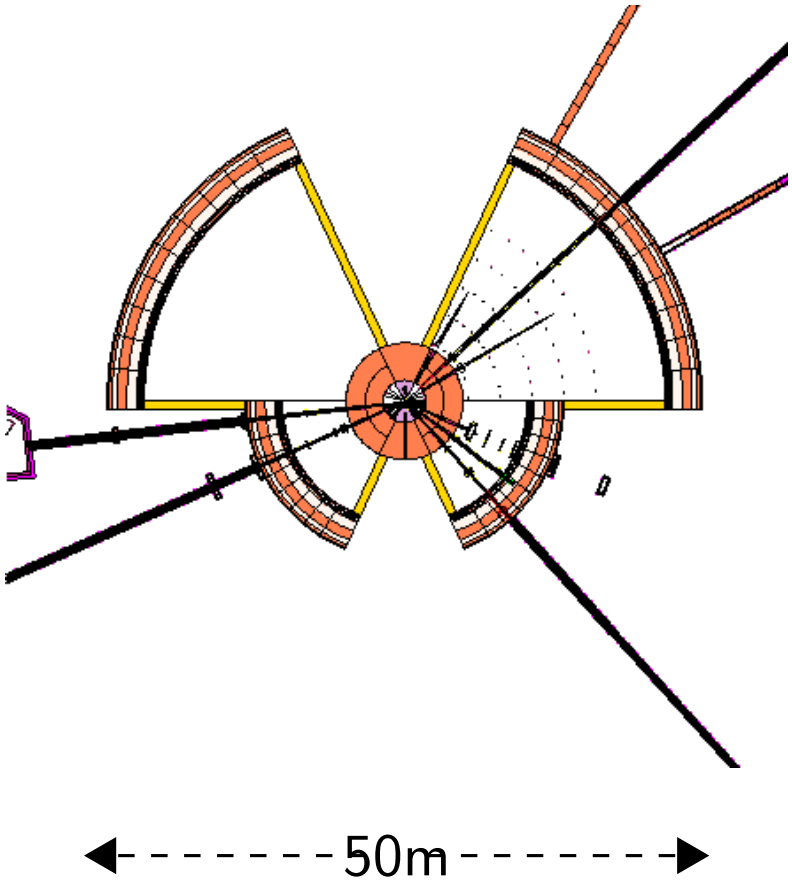
CombLayer use for ESS Facility build



- Multiple instruments contains >90 choppers
- Current MCNP model has 8000 variables
- Essential that model input is prepared by computer code, and results are processed by computer code.

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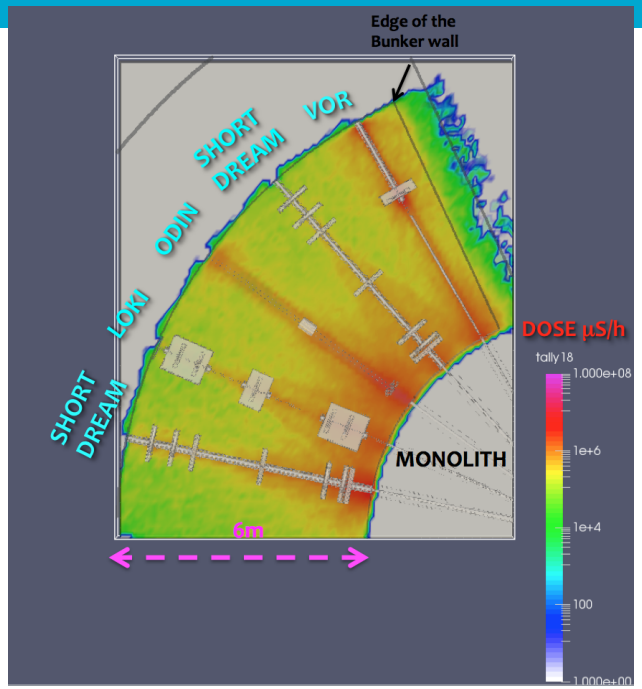
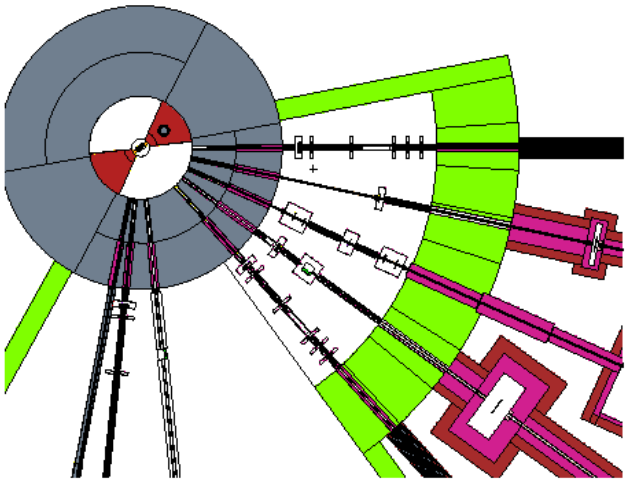
Filled Bunker





- The open bunker cross talk can be simulated
- Model in excesss of 100,000 MNCP cells
- Individual beamlines done by multiple authors and combined

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Variance Reduction

Use an adjoint style variance reduction

- The accuracy of the forward and adjoint flux calculations **for the weight windows** do not need to be high.
- CombLayer uses a simple source-to-cell population followed by Markov Chain iteration (effective multi-scatter)
- Insufficent memory for the angle component when doing big models.

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Adjoint Style Variance reductions

- FW/CADIS system [1] showed how to normalize $q(\boldsymbol{P})$. [position only]
- Extended FW/CADIS-Ω [2] form integrated over angle

$$\phi^{\dagger}(\boldsymbol{r}, E) = \frac{\int_{\Omega} \phi(\boldsymbol{r}, E, \hat{\Omega}) \phi^{\dagger}(\boldsymbol{r}, E, \hat{\Omega})}{\int_{\Omega} \phi(\boldsymbol{r}, E, \hat{\Omega})} \tag{1}$$

[1] J.C. Wagner *et al* Trans. Amer. Nucl Societ. **97** 603 (2007)

[2] M. Munk *et al* Nucl. Sci Eng. (2017)

Practical Variance reduction

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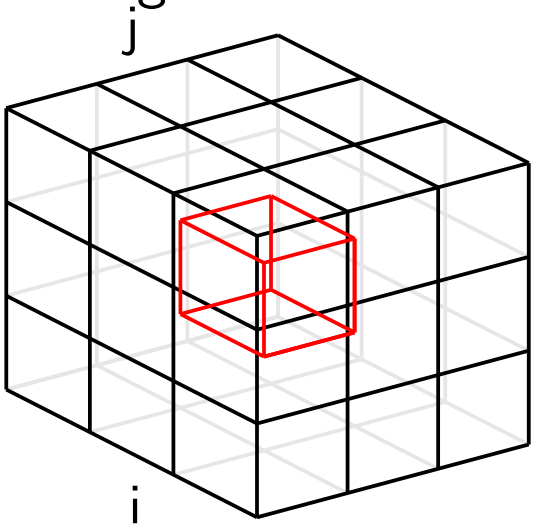
Practical Variance reduction – made fast

- CombLayer **APPROXIMATES** the angle term by nearest neighbour cell directions



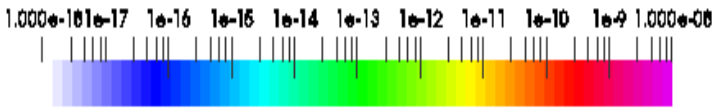
$$\phi^{\dagger}(\boldsymbol{r}, E) = \frac{\int_{\Omega} \phi(\boldsymbol{r}, E, \hat{\Omega}) \phi^{\dagger}(\boldsymbol{r}, E, \hat{\Omega})}{\int_{\Omega} \phi(\boldsymbol{r}, E, \hat{\Omega})}$$

Angular parts proportionate as:

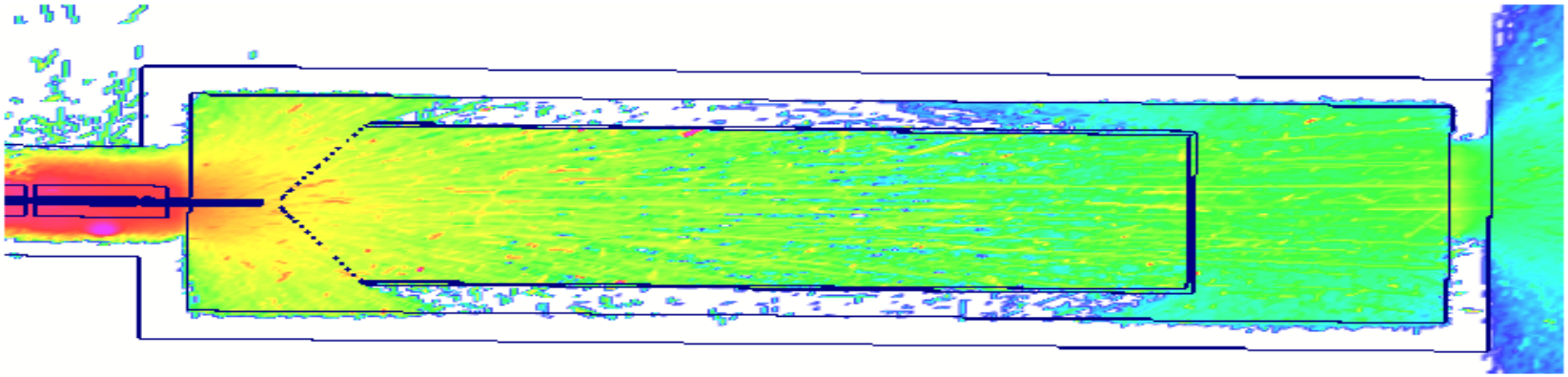
$$\phi(\boldsymbol{r}, E, \hat{\Omega_{ijk}}) = \frac{\phi_{000}(\phi_{000} + (\phi_{ijk} - \phi_{-i-j-k})/2)}{26\phi_{000}}$$

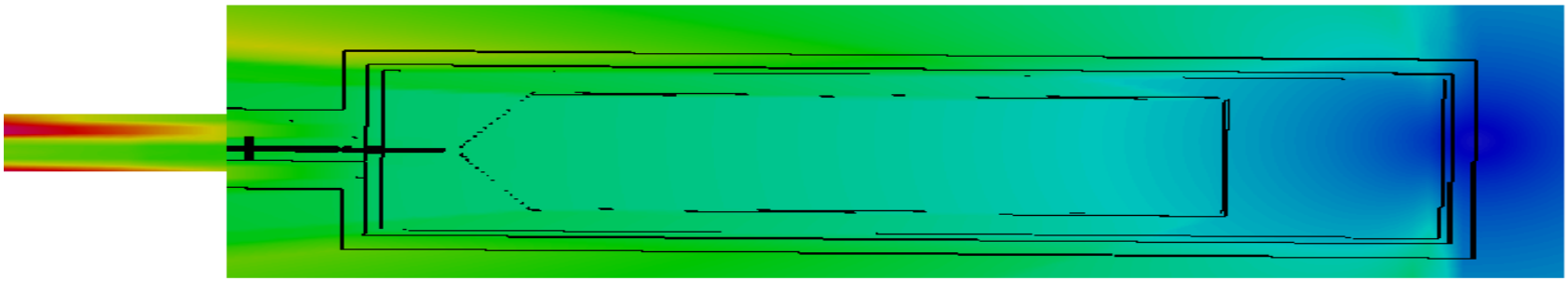
Remember to allow a transport flux in void cells in the Markov-Chain approximation

Background flux in the sample area [32node x 6.5hour run]

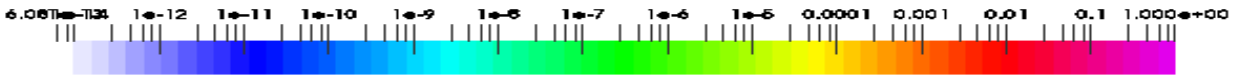


n/proton





WWG



Calculated from proton on target [25m away]

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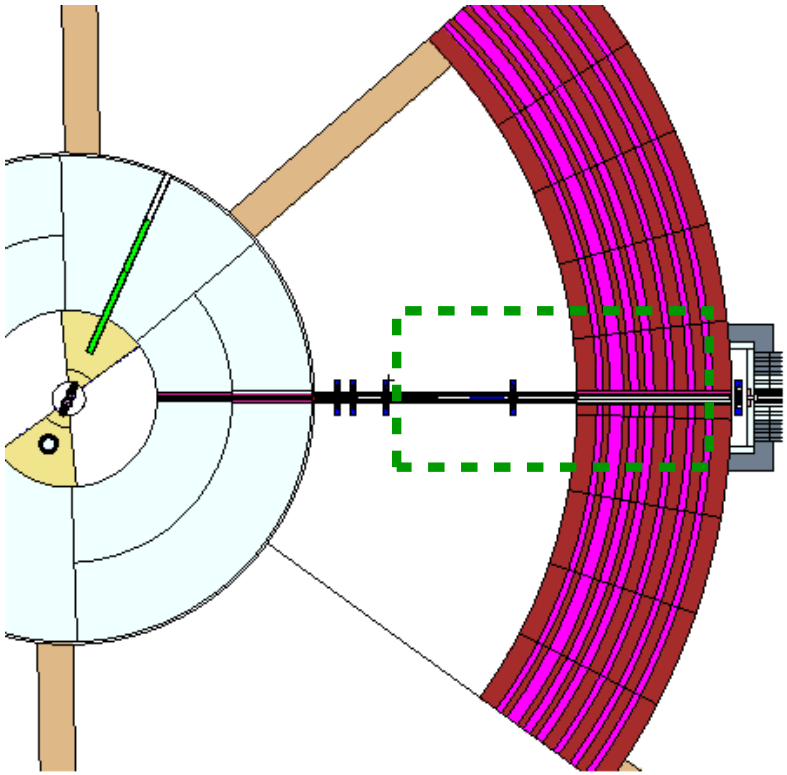
Activation Methodology



- Define volume of interest
- Use activation flag to build MCNP model + variance
- Run model
- Run activation program to proces via cinder for time steps
- Run CombLayer to produce volume sampled gamma spectrum

Optional: Run flux mesh over volume to bias gamma production in individual cells

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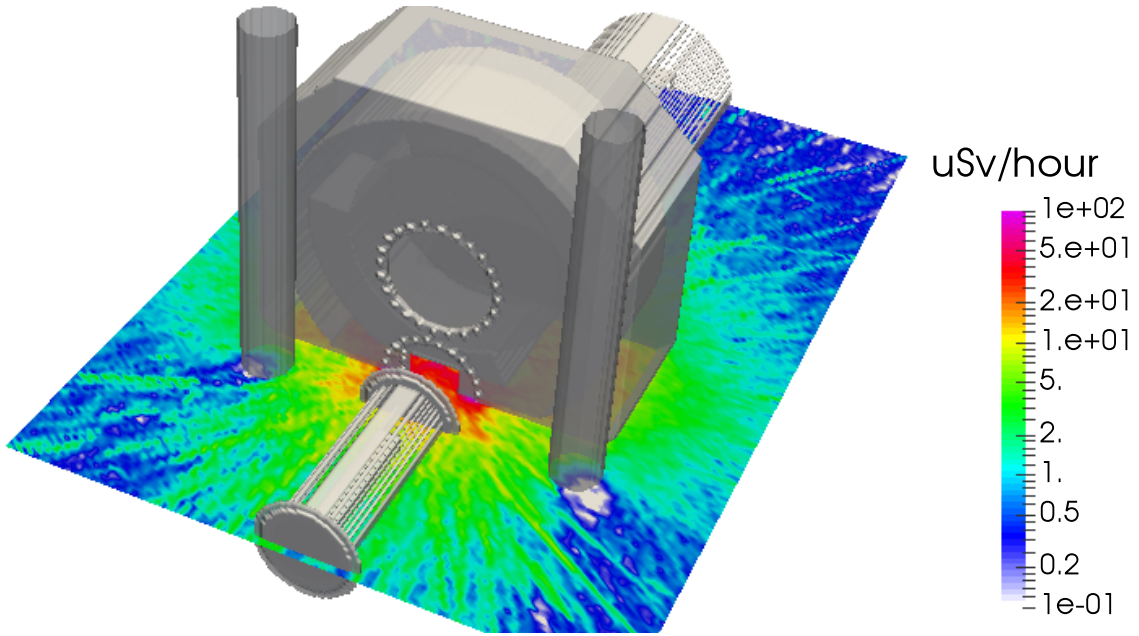
Activation in T0 Chopper



T0-Chopper 7 day: Activation from: Tungsten hammer / Inconnel rotor (80A) / Steel body

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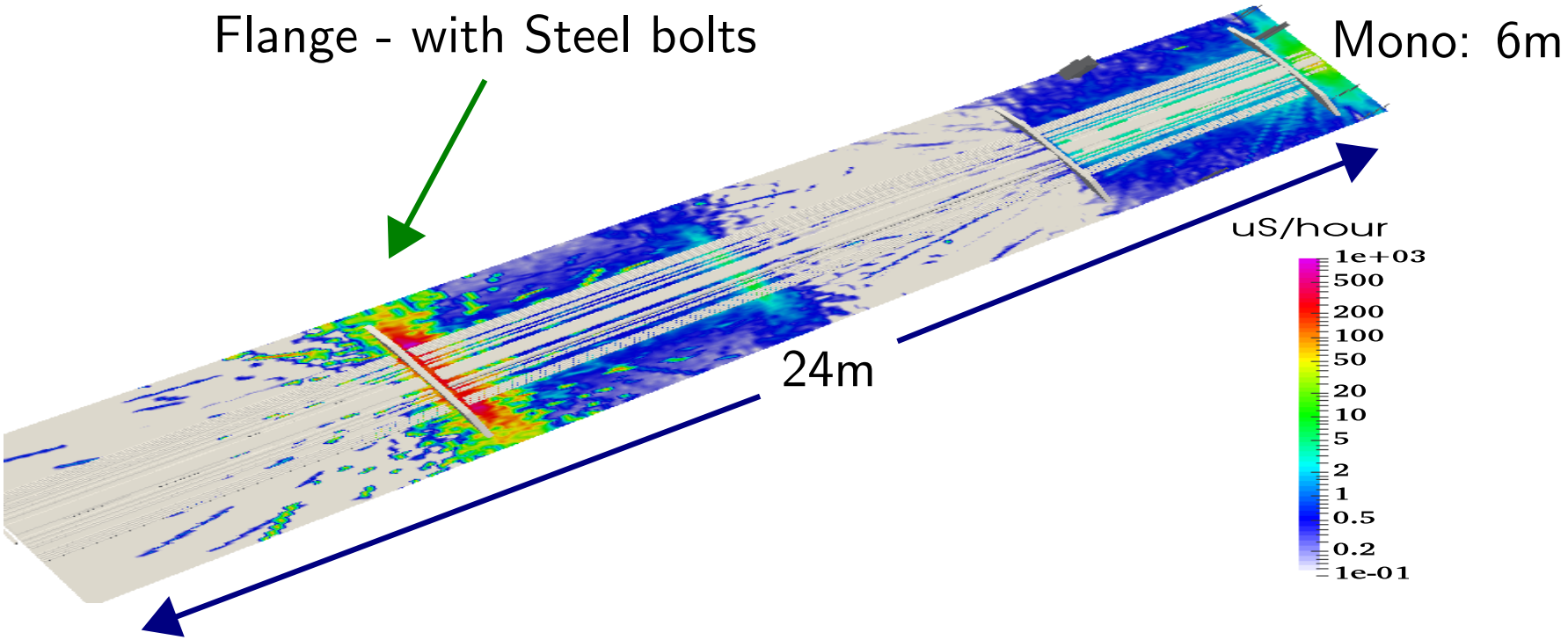
Activation in Guide Elements



Guide 1 day: Activation from: Aluminium guide / Vacuum housing / Silicon windows

Summary

- Simple front end methodology
- Can give approximate gamma dose calculations for very complex systems
- Scales very well in to the 100,000 volume cell models
- Download at https://github.com/SAnsell/CombLayer'

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