Application of Anisotropic Diffusion Coefficient Formalism to RBWR modelling

Nathaniel Read, Eugene Shwageraus

UNIVERSITY OF CAMBRIDGE

Imperial College London

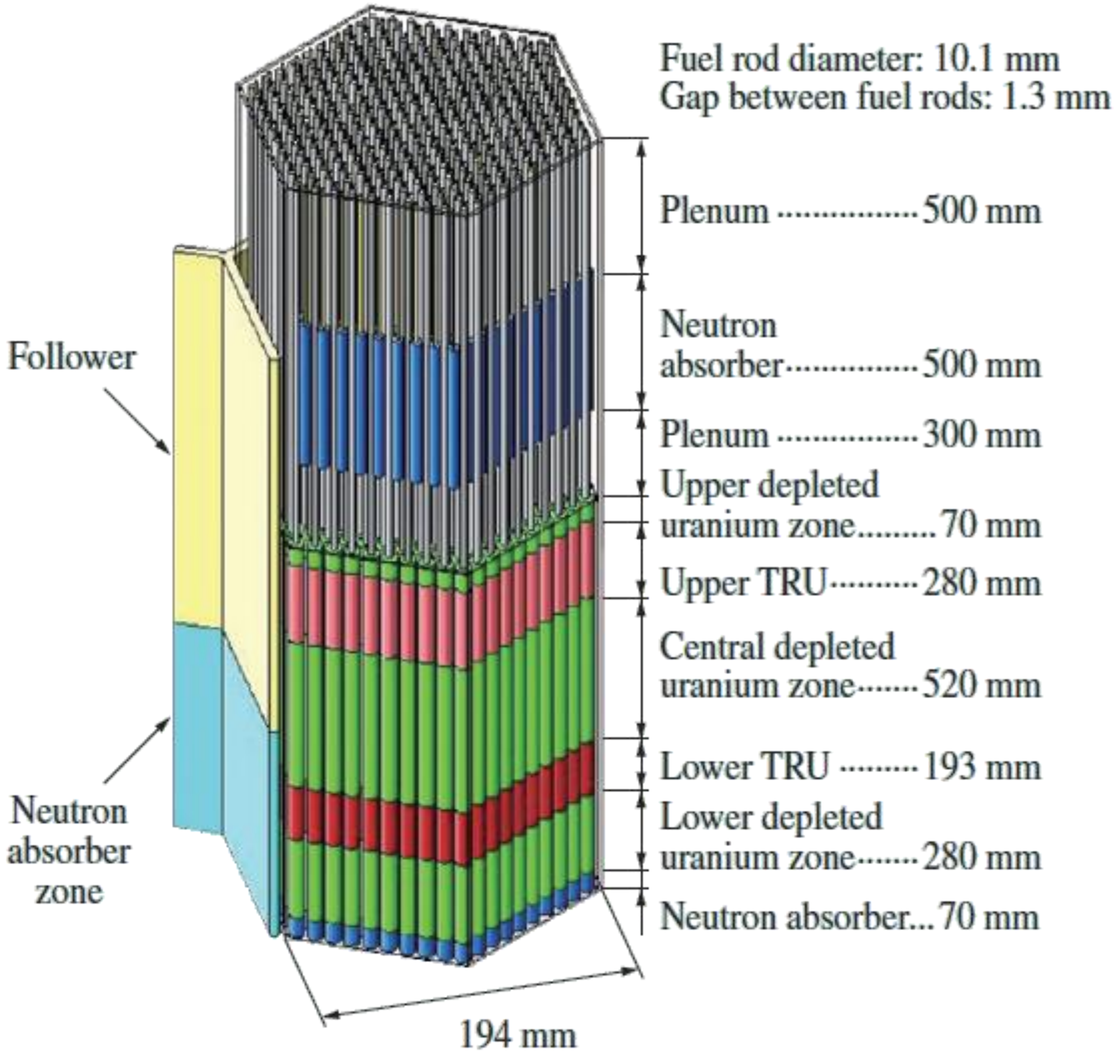
centre for doctoral training

Outline

- Introduction to RBWR
- Anisotropic diffusion coefficient formalism
- Modelling set-up
- Results
- Conclusion

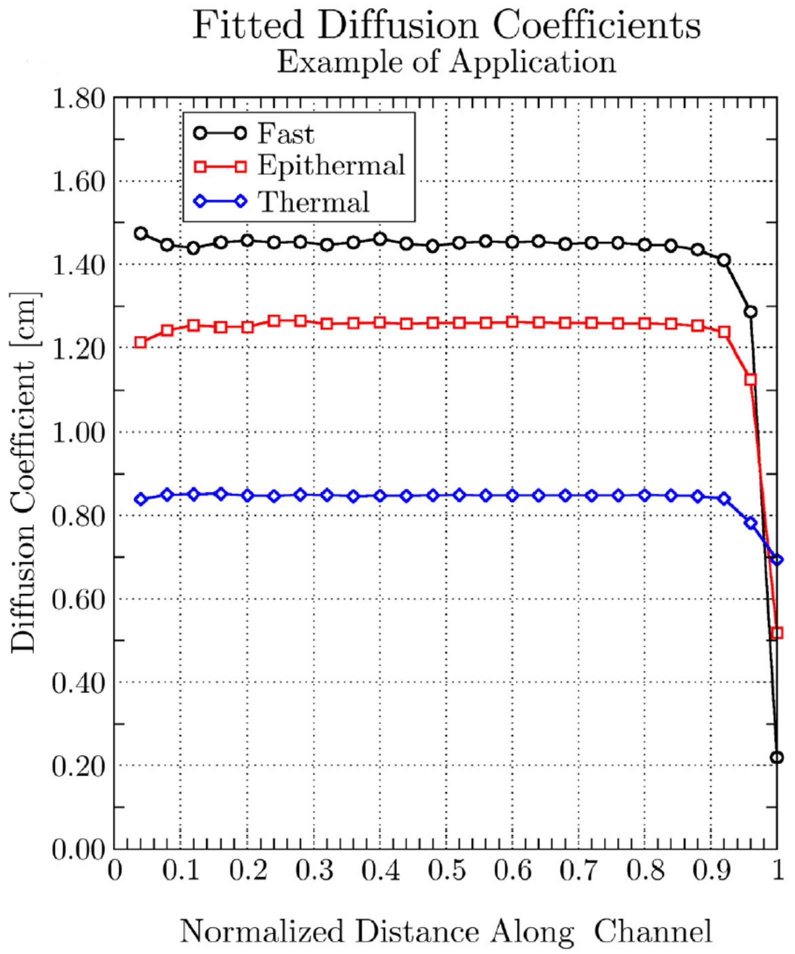
Resource-Renewable BWR

- Unusual layered structure
- High degree of axial heterogeneity
- Axial discontinuity factors required for adequate diffusion calculations
  - Reliance on these could be reduced by new anisotropic diffusion coefficient formalism



Sources of anisotropy

- Anisotropy of material itself e.g. fuel pins
- Anisotropy of scattering laws
- ‘Neighbour effect’:
  - Diffusion coefficient changes near interface with another material
  - Would expect this only in direction normal to interface



Dorval (2016)

Anisotropic diffusion coefficients

- New method implemented in Serpent 2 by Eric Dorval
- Instead of single diffusion coefficient, produces elements of diffusion tensor:

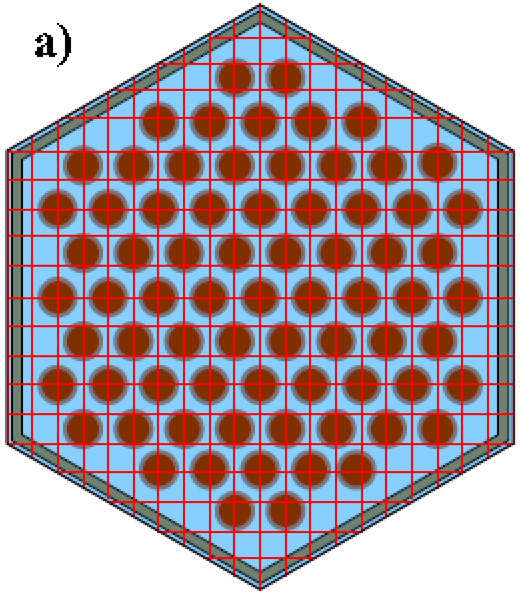
$$\mathcal{D} = \begin{bmatrix} D_{xx} & 0 & 0 \\ 0 & D_{yy} & 0 \\ 0 & 0 & D_{zz} \end{bmatrix}$$

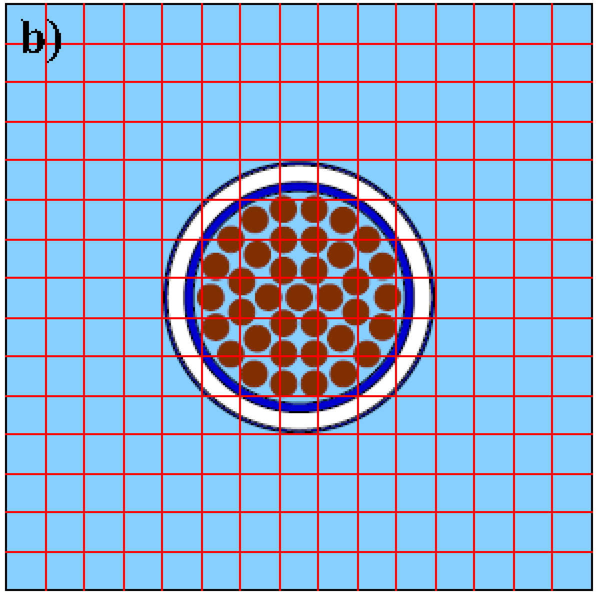
- Might hope that with more physics we can reduce reliance on axial discontinuity factors

Calculating D coefficients (E. Dorval, 2016)

$$\langle \Sigma_t \rangle = \frac{2\, e^2\, \mathrm{Ei}(-2) + 1}{\langle D_n \rangle} = \frac{\alpha}{\langle D_n \rangle}$$

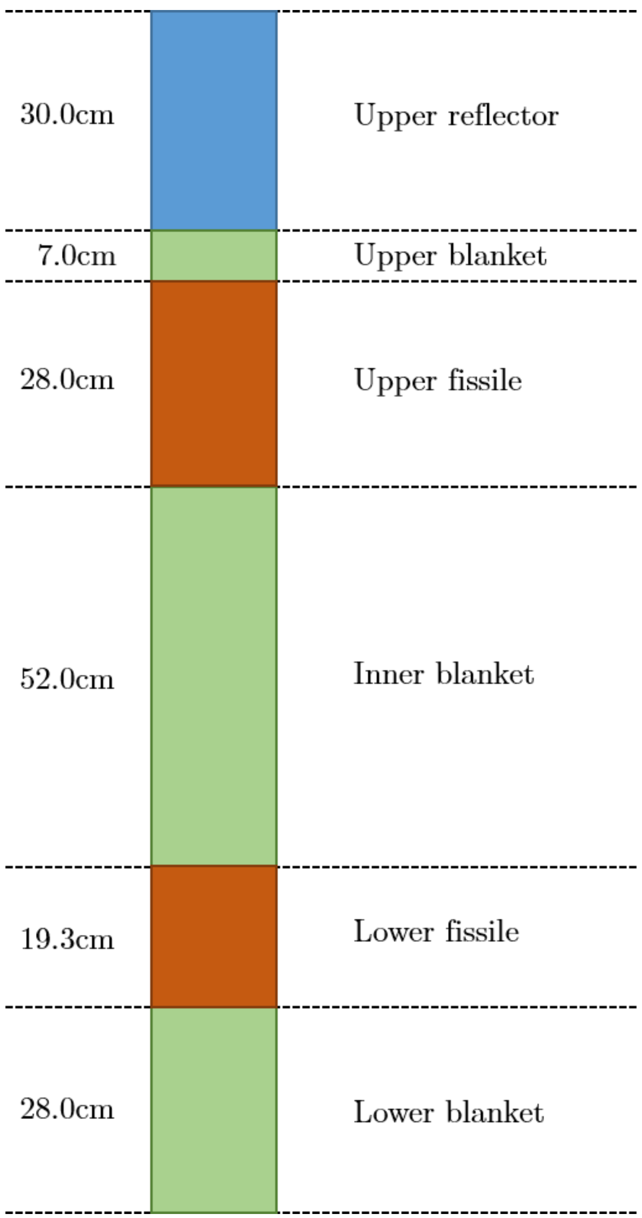
$$\langle \Sigma_{tr} \rangle \,|_{\mathbb{J}} = \, (1 - m) \, \frac{\alpha}{\langle D_n \rangle} \, + \, m \, \langle \Sigma_t \rangle \,|_{\mathbb{J}} \, - \overline{\mu}_0 \, \langle \Sigma_s \rangle \,|_{\mathbb{J}} \, , \quad 0 \leq m \leq 1$$





Modelling set-up

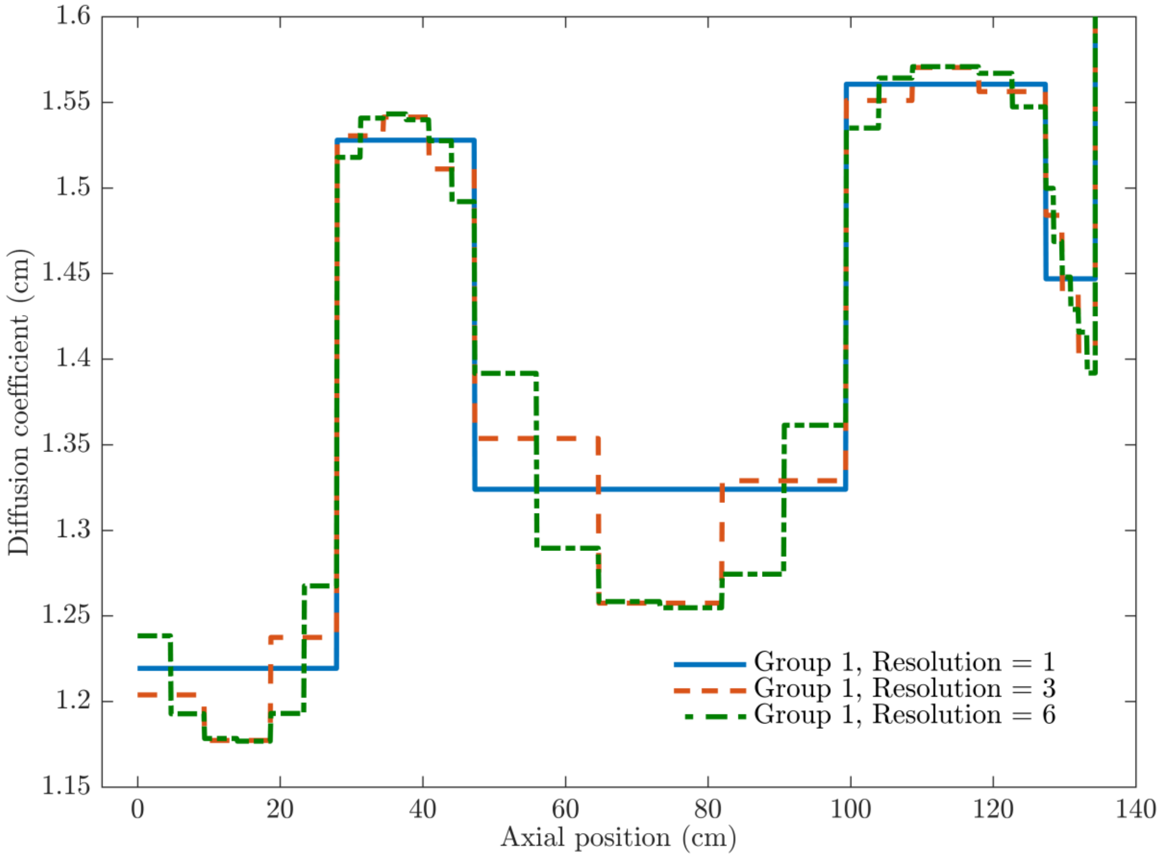
- Simplified RBWR assembly
  - homogenised materials
  - isolating 'neighbour effect'
- 2-group constants produced in Serpent
- Diffusion calculation in OpenFOAM-based solver



Results

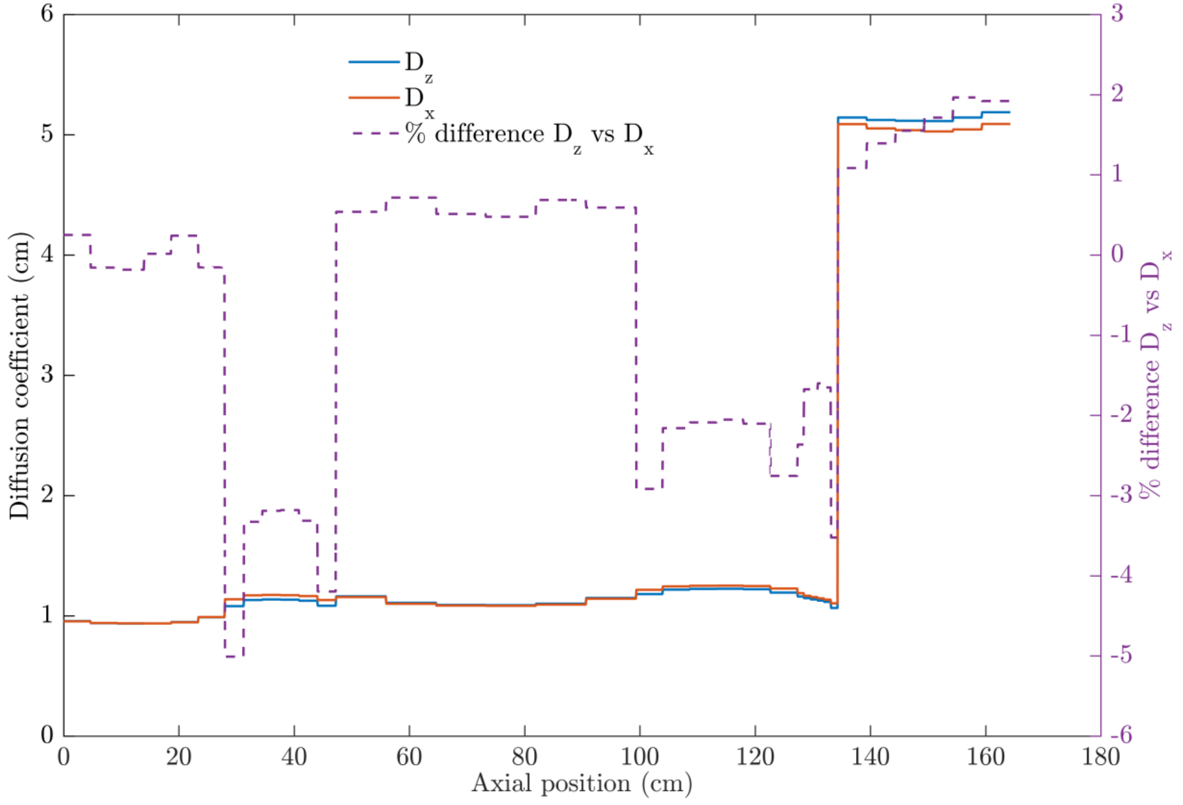
- Hypothesis:

  Anisotropic formalism captures effect of neighbouring materials

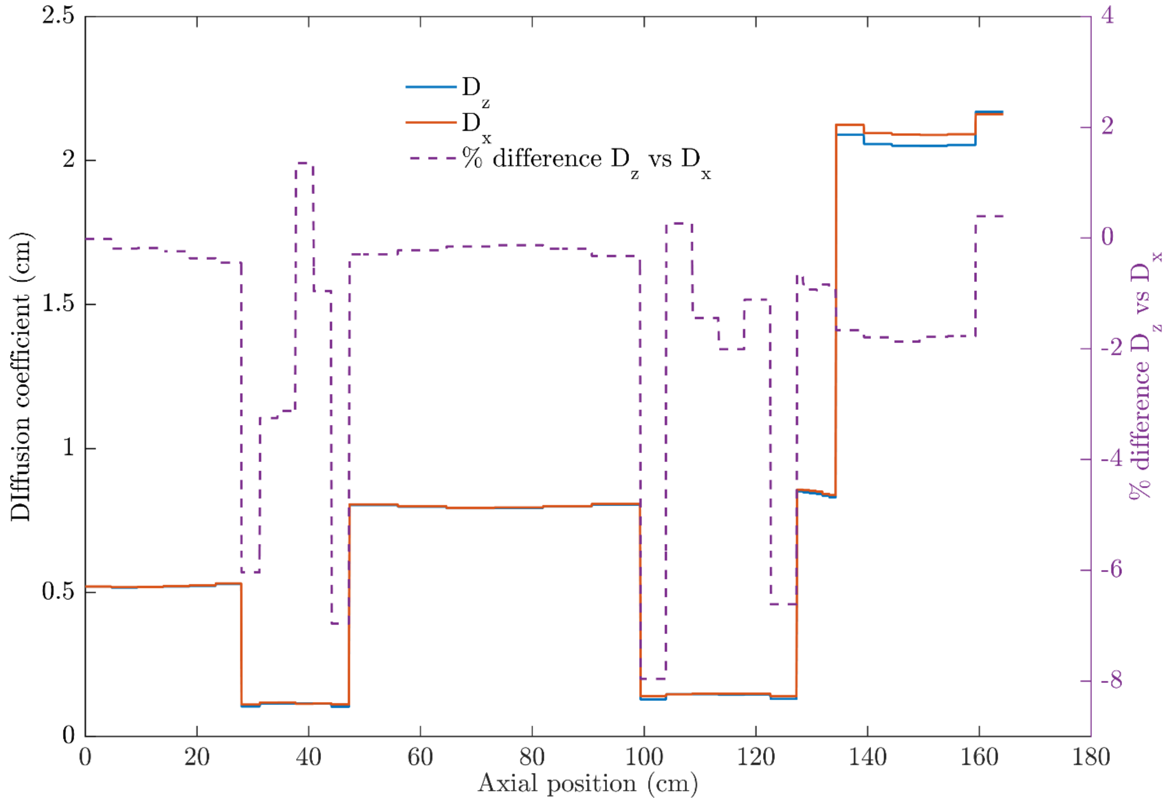


Effect of neighbouring zones

Group 1



Group 2



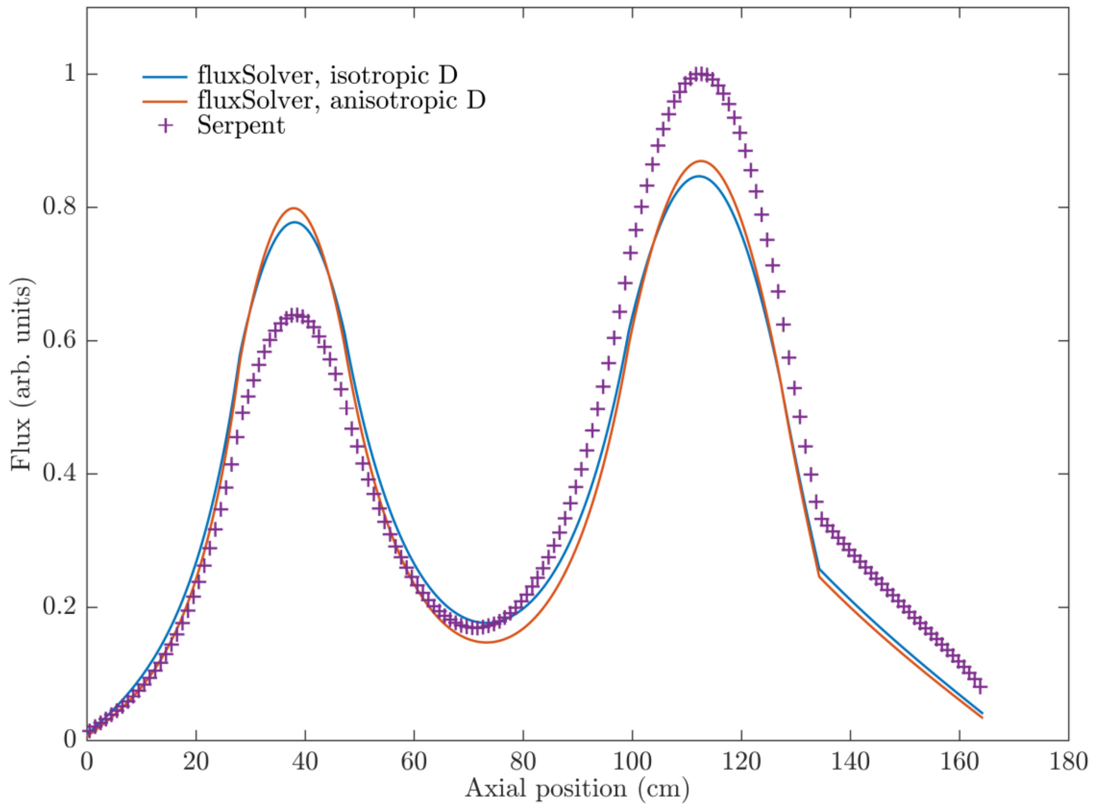
Results

- Using anisotropic formalism offers no improvement vs Serpent reference in this test case:

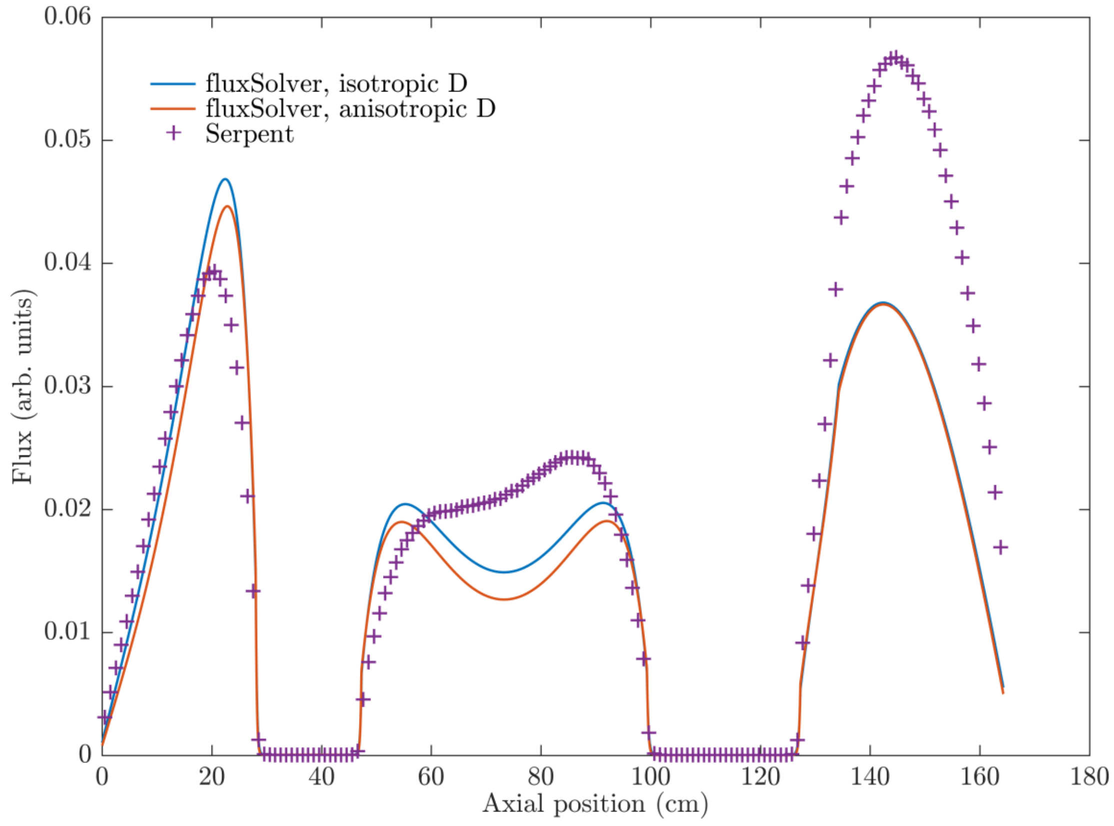
Calculation method	k-eff eigenvalue	Difference vs Serpent
Serpent	1.09254	-
Diffusion w/ **isotropic** diffusion coefficients	1.09767	0.5%
Diffusion w/ **anisotropic** diffusion coefficients	1.13403	3.8%

Flux distribution

Group 1

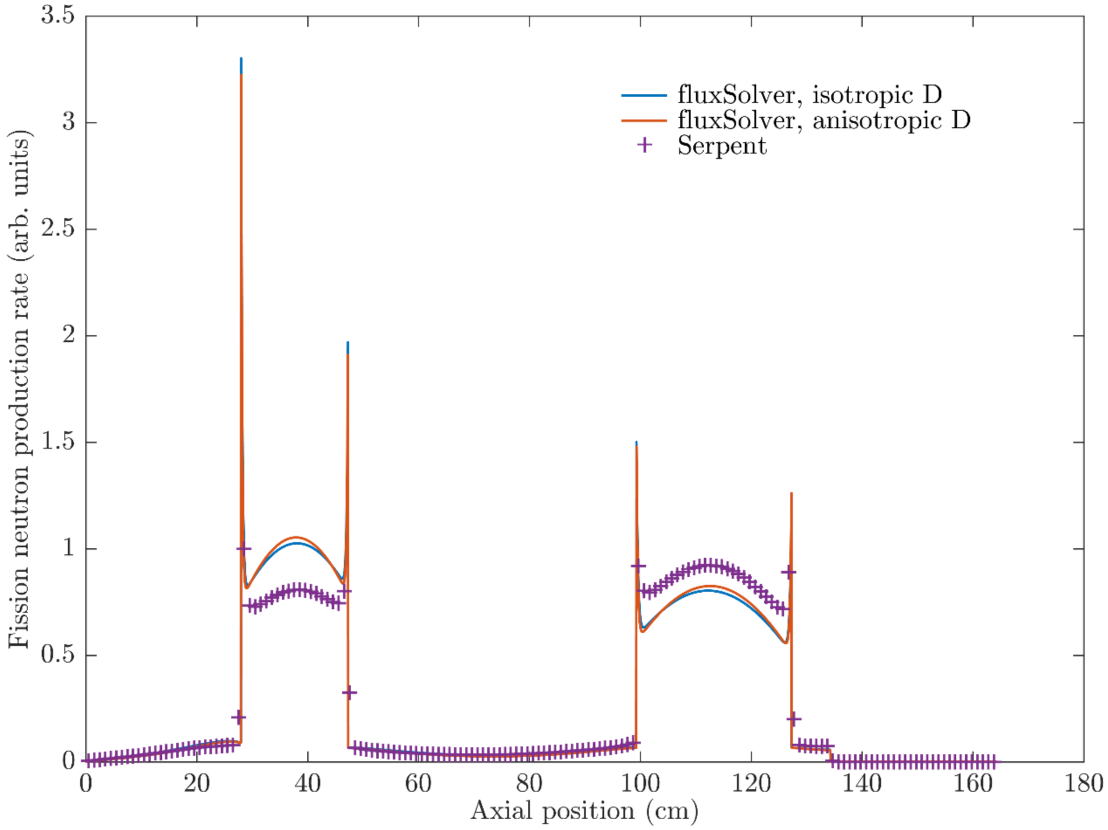


Group 2



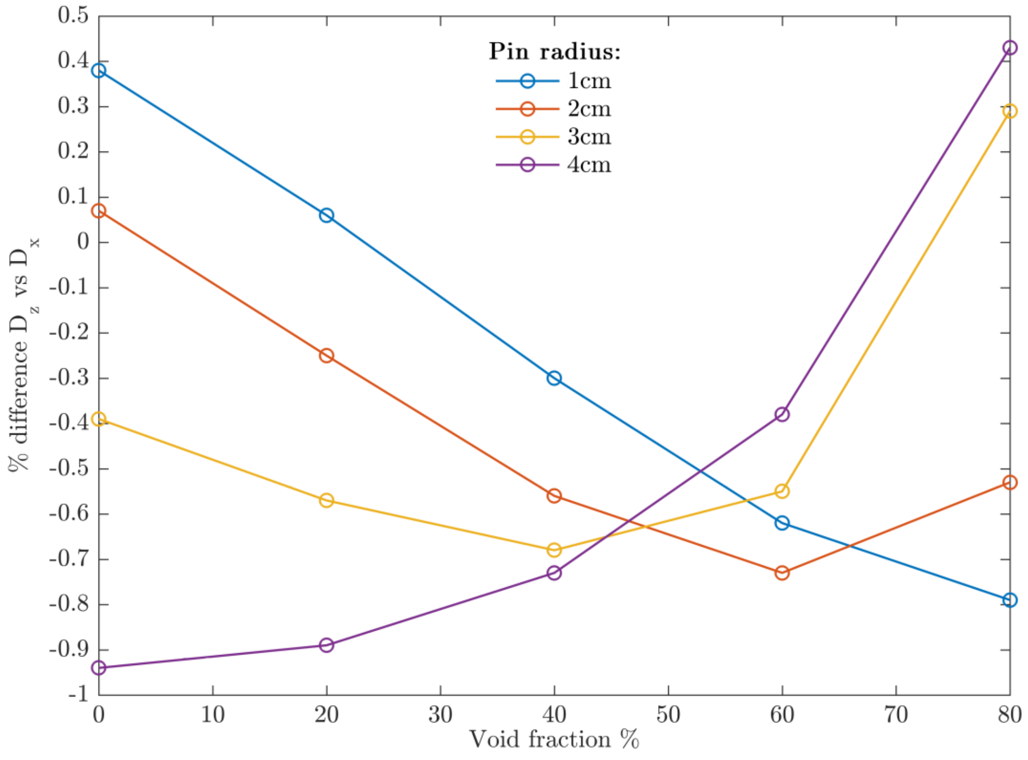
Results

- under both formalisms, fission rate overestimated in one fissile zone and underestimated in another (cancellation of errors):

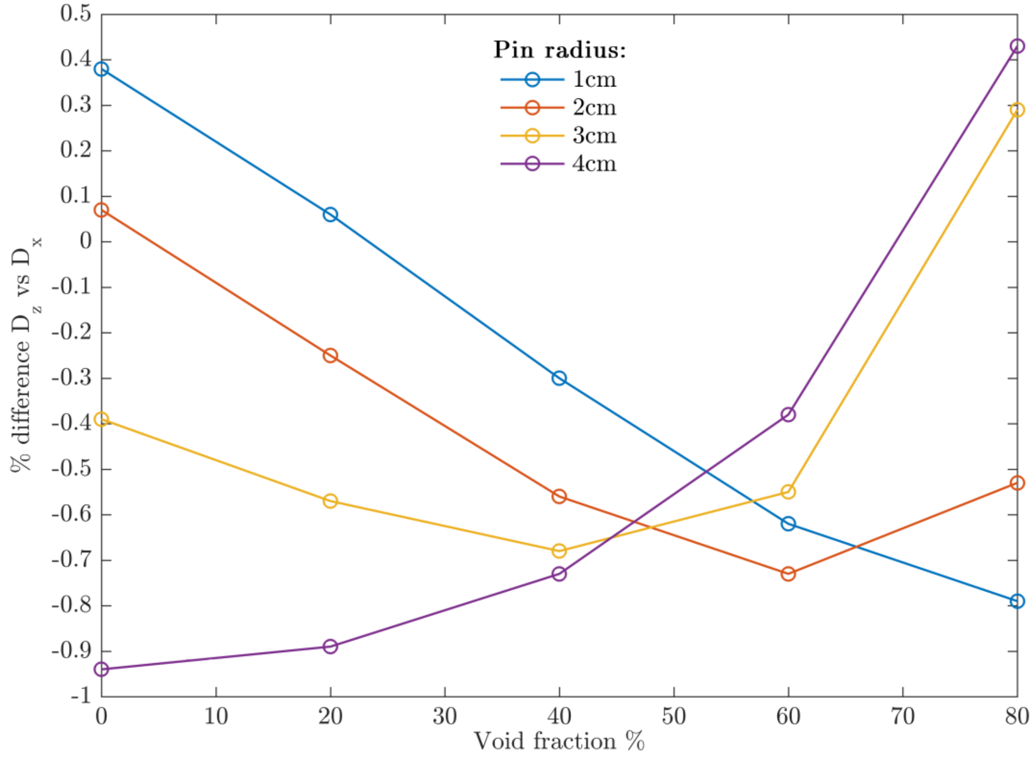


Difference between D_x and D_z

Group 1



Group 2



Importance of anisotropy

***fluxSolver* run**	$\mathbf{k_{eff}}$	**Diff. vs base case**
Base case	1.09767	-
Group 1 D_z decreased by 1%	1.09952	0.17%
Group 2 D_z decreased by 2%	1.09753	-0.01%
Both groups decreased	1.09938	0.16%

Summary and Conclusions

- Analysis of RBWR fuel assembly was attempted using directional diffusion coefficients
- Implemented in OpenFOAM
- D coefficients were generated using new formalism (E. Dorval, 2016)
- The results are not conclusive – no major improvement in accuracy
- Impact of using directional vs anisotropic D was quantified, found to be small in the studied case

References

- Dorval (2016): “Monte Carlo methodologies for neutron streaming in diffusion calculations – application to directional diffusion coefficients and leakage models in XS generation”. PhD thesis, Aalto University.