Serpent International Users Group Meeting , September 15-16, 2011
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Computational Tools for Modeling High Conversion PWRs

By: Dan Kotlyar
Yaniv Shaposhnik
Dr. Eugene Shwageraus

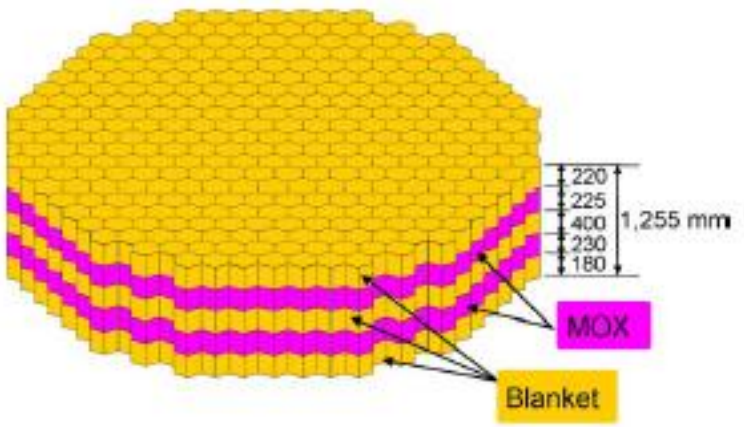
Department of Nuclear Engineering, Ben-Gurion University, Israel

Outline

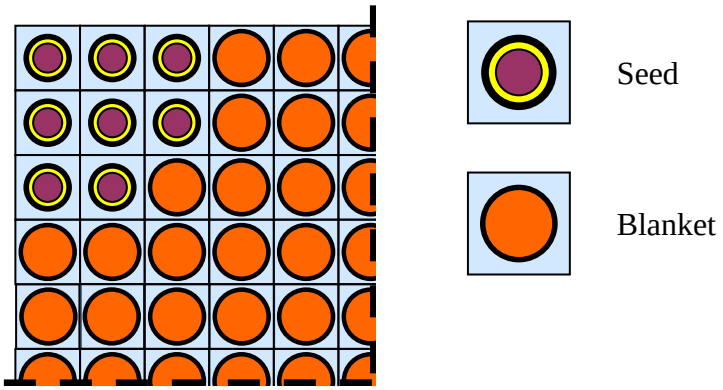
- **Introduction to High Conversion Reactors**
- **Design & Modelling challenges**
- **Objectives:**
  - Comparison of available tools
  - Coupling of MC with TH
- **Computational tools description**
- **Assembly depletion analysis results**
- **Coupling with Thermal Hydraulics**
- **Conclusions & future work**

Introduction to High Conversion Reactors

- Extend energy resources without introducing FBRs
- Use existing LWR technology
  - PWR or BWR
  - U233/Th or U/Pu cycle



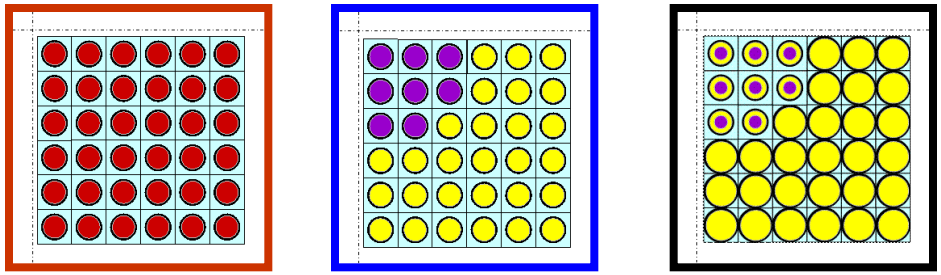
BWR/ Axial heterogeneity / U-Pu

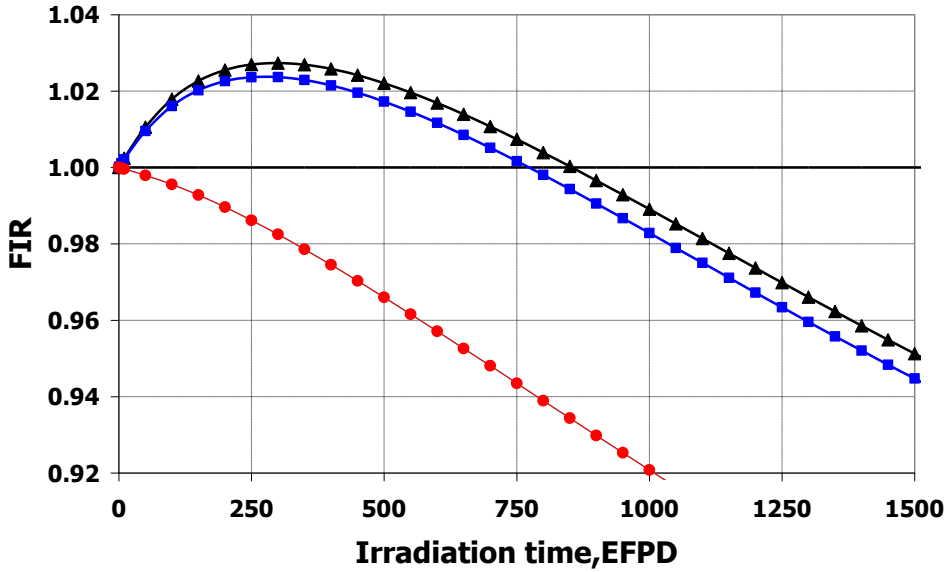


PWR/ Radial heterogeneity / U233-Th

Introduction to the Seed–Blanket design

- Seed
  - Neutron source
- Blanket
  - Neutron absorber
- Separate U & Th pins spatially
  - Maximize neutron leakage from seed to blanket
  - Reduce competition between U^{233} and Th





High CR LWRs Design Challenges

- Careful balance between:
  - Cycle length
  - Positive void coefficient
  - Fissile Inventory Ratio > 1

$$FIR = \frac{Fissile\ \ mass\ at\ \ time\ \ t}{Initial\ \ \ fissile\ mass}$$

- Objectives can be met by using heterogeneous fuel geometry (Seed – Blanket)
  - High power peaking

High CR LWR Modeling Challenges

- High flux gradients
  - Diffusion approximation ?
- High spectral shifts
  - Many energy groups
- High power peaking
  - Couple with TH ?

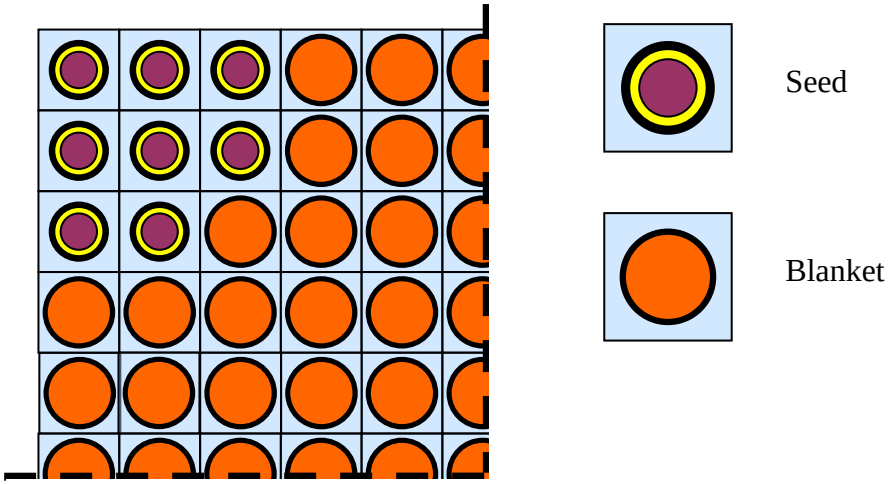
Objectives:

- **Compare available codes**
  - Deterministic transport
    - BOXER
  - Monte-Carlo transport
    - BGCore
    - Serpent
- **Demonstrate coupling of MC with TH**

Computational Tools

- **Serpent**
  - Woodcock delta-tracking
  - Unified energy grid
  - Reduced execution CPU time
  - Increased memory requirements
- **BGCore**
  - MG approach
  - Integrated TH feedback
- **ELCOS**
  - BOXER- cell and 2D transport
  - SILWER – 3D with TH

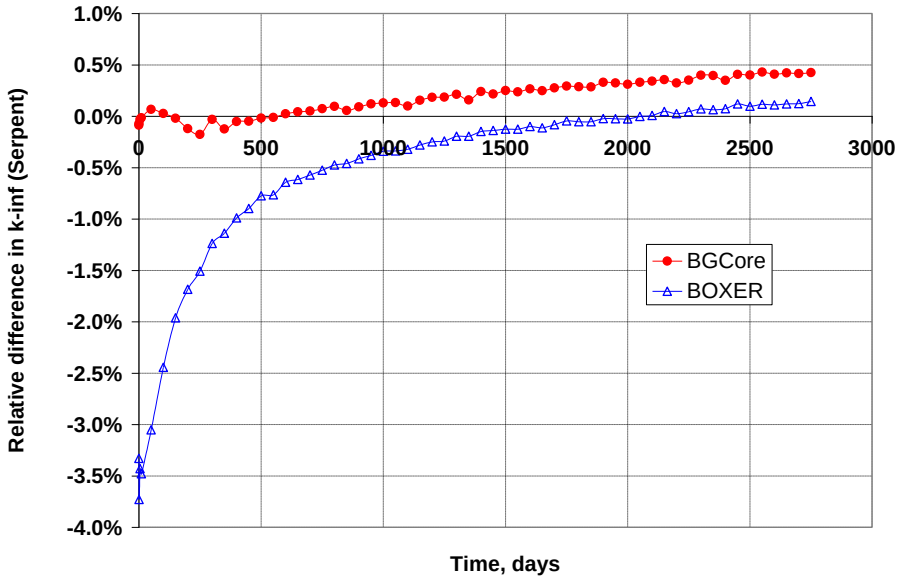
2D Neutronic design



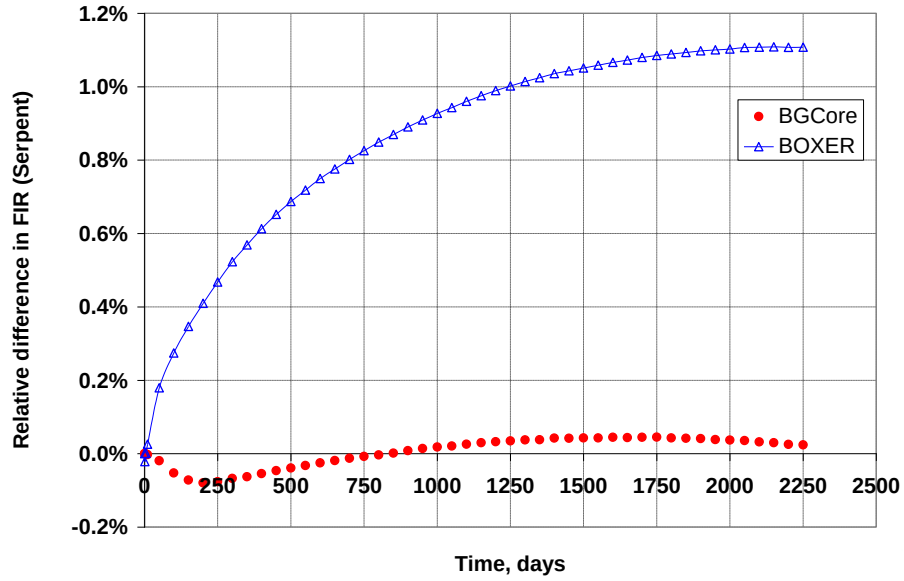
- Assembly size 11x11
- Duplex Seed fuel pins
  - Inner seed – contains most of the initial ^{233}U (21 $^{w}/_{0}$)
  - Outer seed – acts as blanket
- Hydride Blanket fuel pins

2D Burnup results

	Serpent	Relative Diff (%) to Serpent	
	K-inf	BGCore	BOXER
BOL	0.91	0.09	**3.33**
EOL	1.00	0.40	0.20

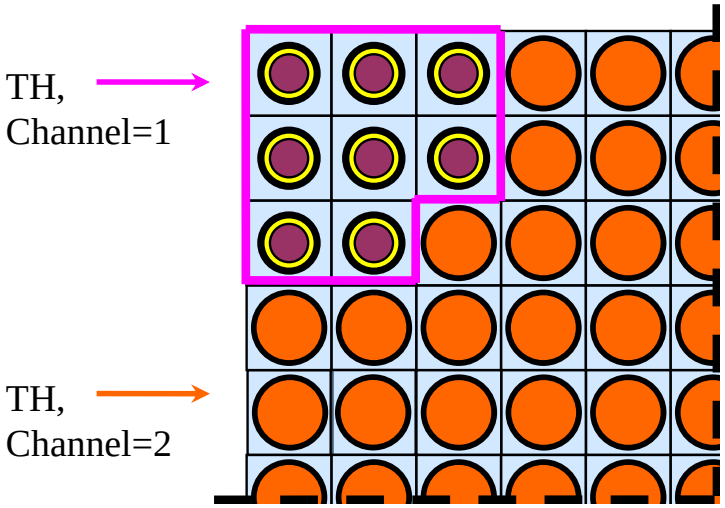


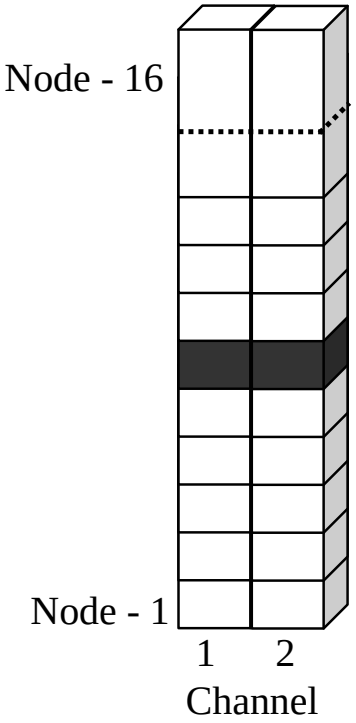
	Serpent	Relative Diff (%) to Serpent	
	FIR	BGCore	BOXER
EOL	0.82	0.05	**1.04**



3D Neutronic TH design

- Radial configuration
  - 3 - Neutronic regions
  - 2 - TH channels
  - Reflective boundary
- Axial configuration
  - 16 - Neutronic regions
  - 16 - TH nodes
  - Finite boundary

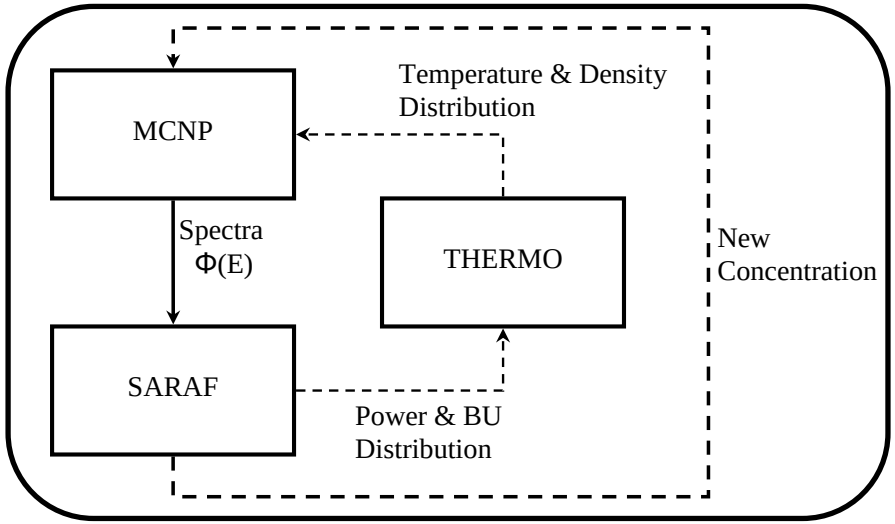




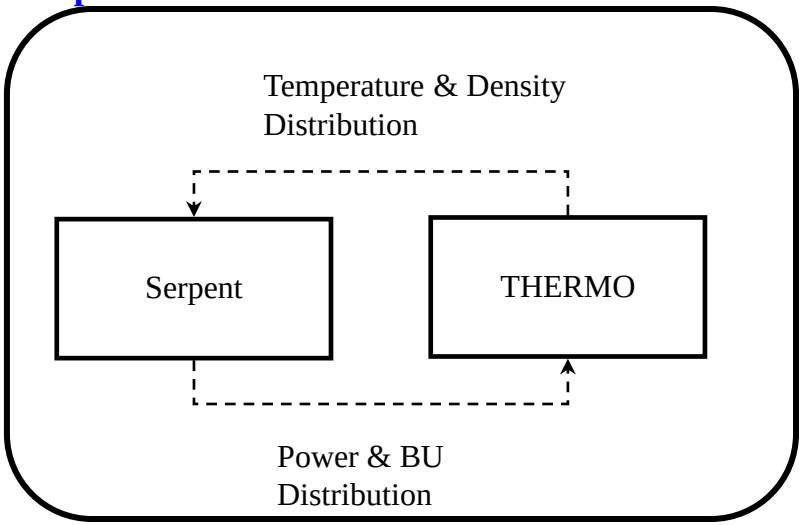
Neutronic–TH Coupling Methodology

- BOL calculations
  - Moderator
    - Density
    - Temperature
  - Fuel
    - Temperature (Doppler)

BGCore

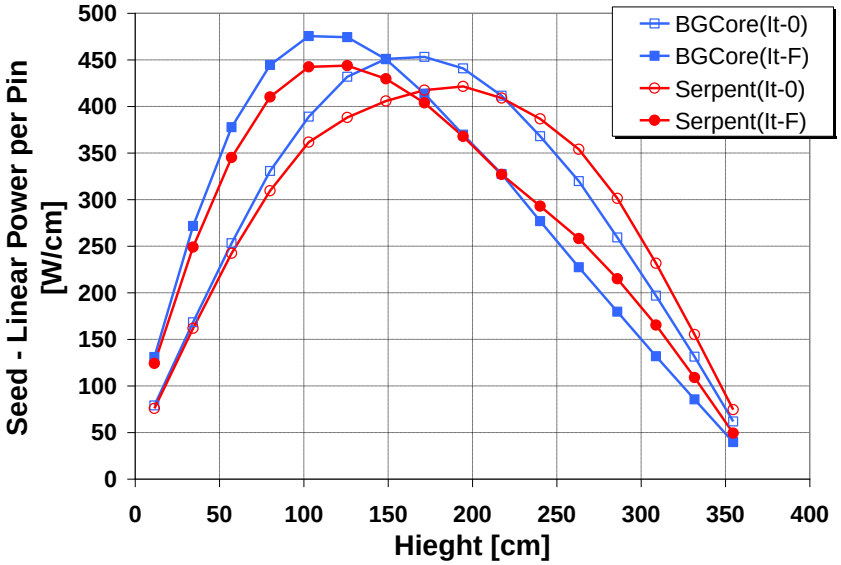


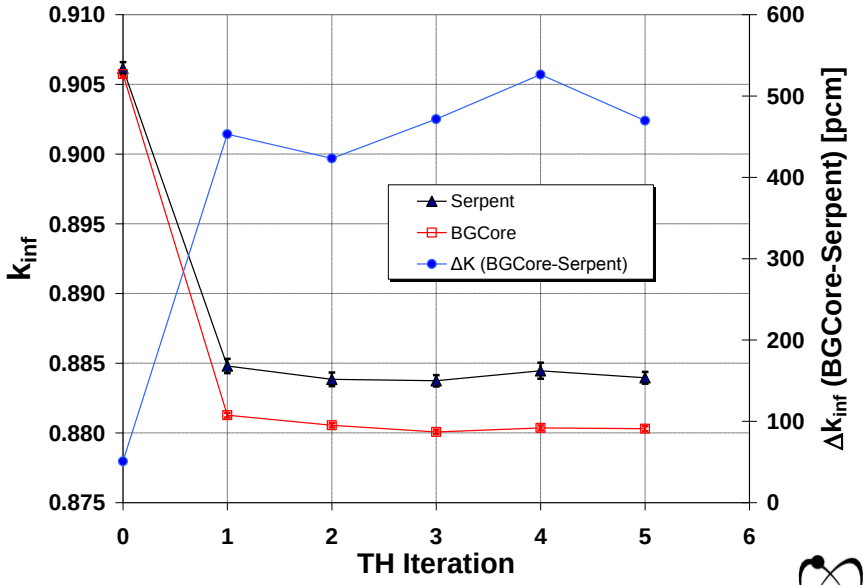
Serpent



Neutronic–TH Results

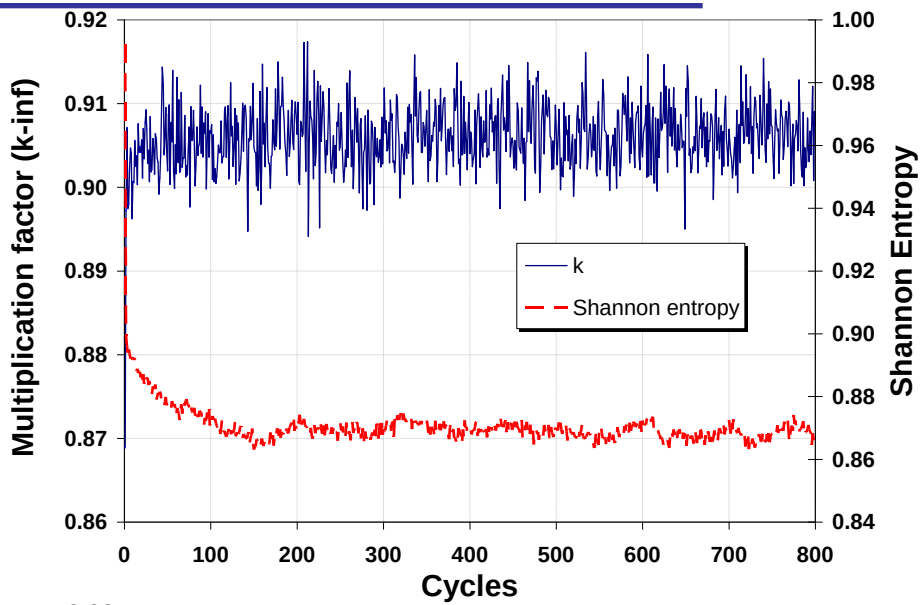
- Iteration zero
  - Density = constant
  - Temperature = constant
  - Cross sections = constant
  - Asymmetric power shape
  - Δk_{inf}(BGCore-Serpent) = 50 pcm
- Relatively large differences
  - Power – Iterations “0” & “F”
  - k_{inf} – Iterations “F” (450 pcm)
- Fission source convergence
  - **Shannon entropy**



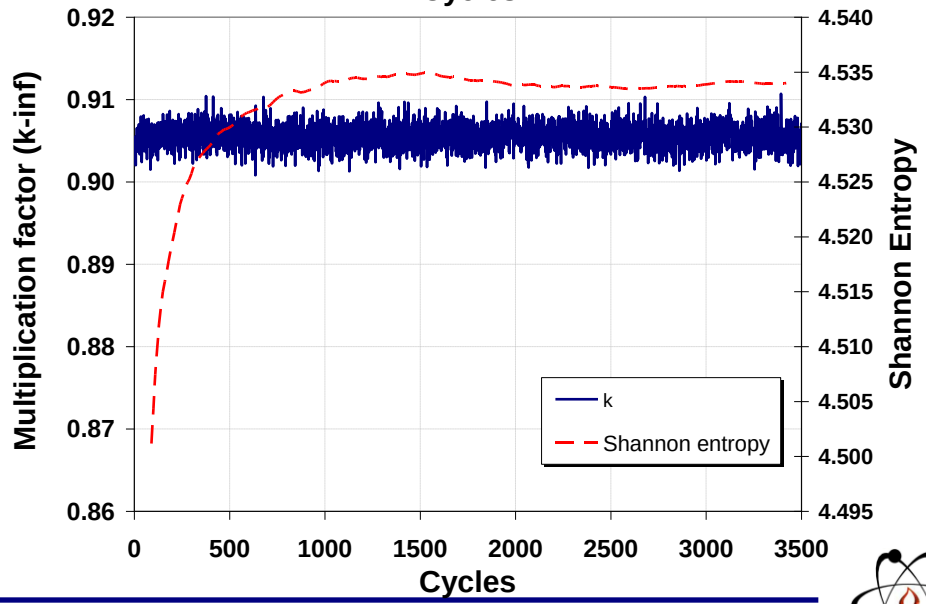


Fission source convergence

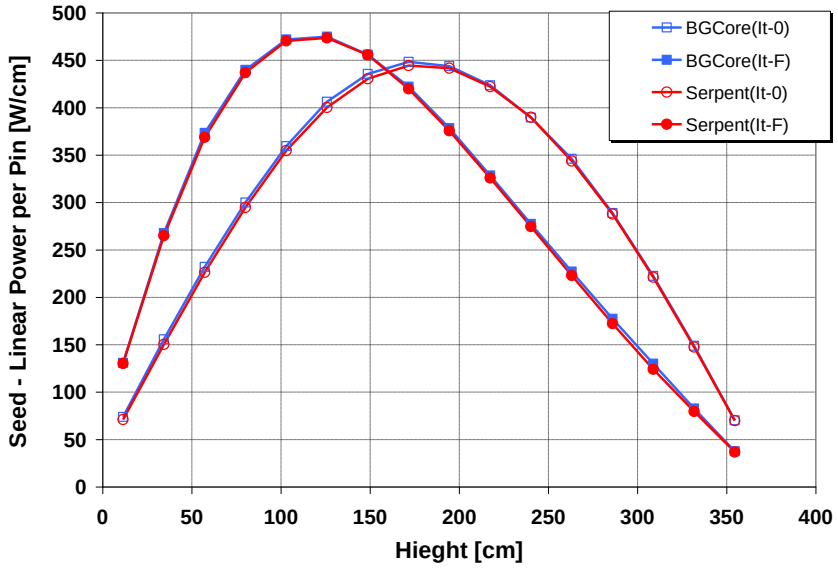
- **Serpent**
  - 300K Histories
  - 300 Inactive cycles
  - 200 Active cycles

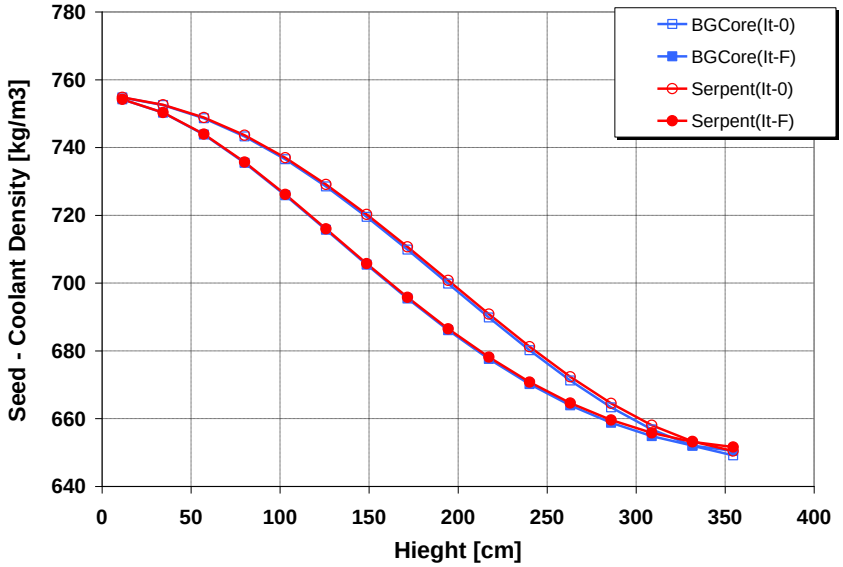


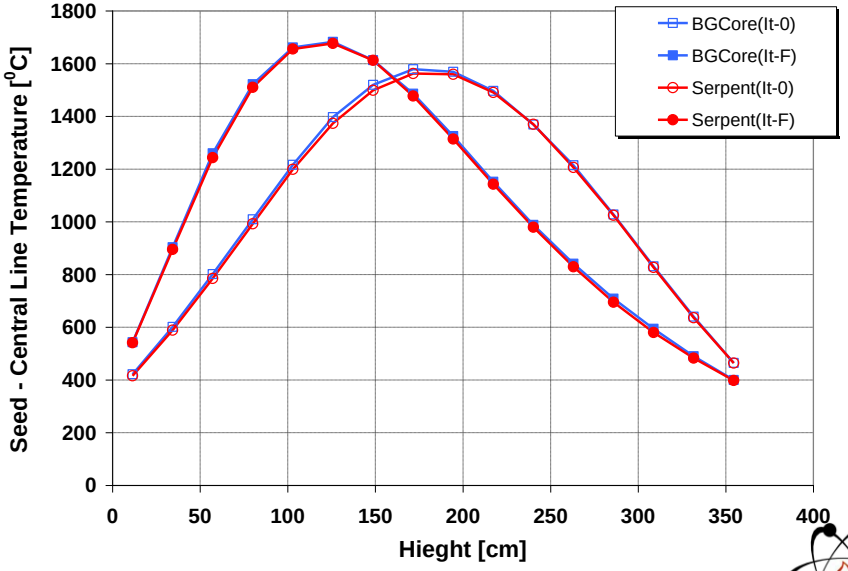
- **BGCore**
  - 350K Histories
  - 1000 Inactive cycles
  - 200 Active cycles



Neutronic–TH Converged Results







Summary

- **Burnup analysis**
  - ✓ BOXER
  - ✓ Serpent
  - ✓ BGCore
- **Good agreement between the MC codes**
  - Neutronic-Depletion
  - Neutronic-TH
- **Feasibility of Serpent-TH coupling**
  - Superior source convergence
- **Future work:**
  - Built-in fission source convergence routine
  - Full integration of Serpent-THERMO

THANK YOU