BASIC RESEARCH ON HIGH TEMPERATURE GAS REACTOR THERMAL HYDRAULICS AND REACTOR PHYSICS

Task 2

Coupled Reactor Physics and Thermal-Hydraulics Modeling

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Todd Palmer Oregon State University
Karen Vierow TAMU
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February 23, 2009
TAMU

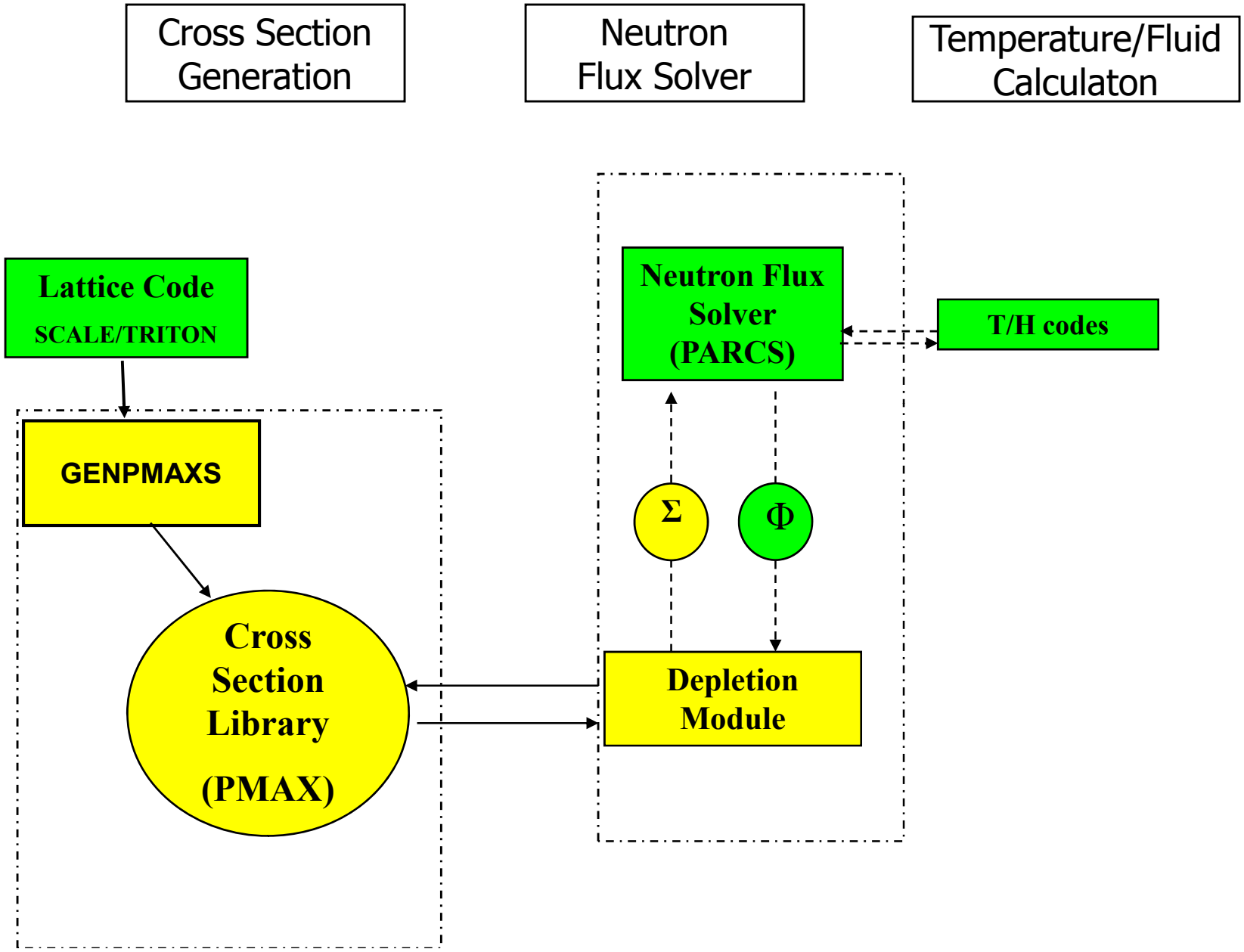
Task 2: Subtask List

- **Task 2A HTR Cross Section Generation (MICH/TAMU)**
  - **2.A.1 SCALE (TRITON) Interface w/ PARCS (FY09) Tom**
  - **2.A.2 Benchmarking of SCALE/PARCS (FY09) Volkan**

- **Task 2B HTR Reactor Core Neutronics (MICH/OSU)**
  - **2.B.1 Core Depletion and Equilibrium Cycle (FY10)**
  - **2.B.2 Upgrade Flux Solution Methods**
    - **Cylindrical Nodal (FY09) Todd**
    - **Transport Nodal (FY09)**
    - **Hybrid Monte Carlo (FY09)**
    - **Hot Spot Factor Calculation (FY10)**

- **Task 2C MELCOR (TAMU/MICH)**
  - **2.C.1 Qualification of MELCOR for the HTR (FY09) Karen**
  - **2.C.2 Coupling of PARCS to MELCOR (FY09) Pavel**

U.S. NRC Coupled Code System



SCALE Overview

- The SCALE (Standardized Computer Analysis for Licensing Evaluation) has been developed for and with the support of DOE and NRC since 1980.
- Widely used tool for reactor, criticality, and fuel cycle confirmatory analysis by NRC, DOE, academia and industry worldwide.
- Rigorous Code System Quality Assurance
  - Configuration management
  - Module and data revision control
  - QA surveillance and auditing
  - Full documentation available electronically with distribution
  - Numerous public V&V reports
  - Portable – Windows/Macintosh/Linux/Unix

Core Analysis using TRITON and PARCS

- First established TRITON/PARCS functionality for LWR (MOX) confirmatory analysis
  - DeHart, MD, AP Ulses and J Saccheri 2005. "Assessment of TRITON and PARCS for Full-Core MOX Fuel Calculations,", vol.92, 2005 pp.763-766 *American Nuclear Society 2005 Annual Mtg, San Diego, CA USA*
- This work has continued in transient BWR analysis for ESBWR and Peach Bottom transient analysis
  - DeHart, MD, 2008. Generation of Lattice Physics Analysis and Cross Section Data for ESBWR Fuel Using TRITON, ORNL Letter Report
  - DeHart MD et al., 2006: Application of TRITON-TRACE/PARCS to the Analysis of Peach Bottom Unit 2, Cycle 1, ORNL Letter Report
- Ongoing development of HTGR analysis capabilities and validation benchmarks.
  - DeHart MD and ML Pritchard, 2008. "Validation of SCALE and the TRITON Depletion Sequence for Gas Reactor Analysis," vol 99, American Nuclear *Nuclear Society 2008 Winter Mtg, Reno, NVUSA*

Recent SCALE Activities

- SCALE 6 released on Feb 12, 2009
- Includes new capabilities and features applicable to HTR:
  - Support for particle fuels (double heterogenity) in depletion calculations
  - ENDF/B-VII cross section libraries
  - Continuous Energy Monte Carlo
  - Improved coupling with PARCS
- A computational benchmark for the depletion analysis of doubly heterogeneous fuel types has been developed and distributed internationally
- ORNL, U of Michigan, and Texas A&M U have met to coordinate development and testing schedules

Excerpts from January ORNL Meeting Minutes

Phase 1: Infinite lattice calculation

This benchmark will demonstrate that cross sections are being properly homogenized by TRITON and that cross sections and branches are correctly translated into PARCS format by GenPMAXS. *Planned completion date: April 10, 2009*|

Phase 2: Infinite lattice, finite height

The assembly model developed in Phase 1 will be extended to three dimensions by modeling a finite-height assembly. These calculations will be compared to the results of three-dimensional KENO-VI assembly models for the two assembly temperature profiles. *Planned completion date: April 30, 2009*

Phase 3: Finite lattice core calculation

This will provide the first experimental validation point for the TRITON/PARCS methodology; both steps demonstrate the applicability of the process to prototypical core designs. *Planned completion date: July 31, 2009*

Phase 4: Pebble-bed calculation

Planned completion date: September 30, 2009

Meeting scheduled at NRC on March 23-24 to finalize Coordination/Benchmark.

PARCS

A Multidimensional Multigroup Reactor Kinetics Code Based on the Nonlinear Nodal Method

Prepared for Release of PARCS / NRC-V3.0

Thomas J. Downar
Y. Xu V. Seker

January, 2009

PARCS Neutronics Methods: Solution Kernels

Geometry Type	Kernel Name	Solution Method	Energy Treatment	Angle Treatment
Cartesian 3D	CMFD	FD	2G	Diffusion
	ANM	nodal	2G	Diffusion
	FMFD	FD	MG	SP3
	NEMMG	nodal	MG	SP3
Hexagonal 3D	**CMFD**	**FD**	**2G**	**Diffusion**
	TPEN	**nodal**	**MG**	**Diffusion**
Cylindrical 3D	**CMFD**	**FD**	**2G**	**Diffusion**
	FMFD	**FD**	**MG**	**Diffusion**

CMFD = Coarse Mesh Finite Difference
ANM = Advanced Nodal Method
FMFD = Fine Mesh Finite Difference
NEM = Nodal Expansion Method
MG = Multigroup

Code Capabilities

- **PARCS** - U.S. NRC Advanced Reactor Core Neutronics Simulator
  - Solves 3D, Time Dependent Core Flux/Power Equations
  - Solves 3D Flux in both Cylindrical (PBMR) and Hexagonal (PMR) Geometry
  - Benchmarked for PBMR with OECD PBMR-400 Benchmark [Reitsma, 2007], [Seker, 2006]

- **AGREE** - **A**dvanced **G**as **RE**actor **E**valuator
  - Solves 3D, Time Dependent Porous Medium (PBMR) Mass, Energy, and Momentum Equations for Gas Reactor
  - Coupled to PARCS to provide coupled time-dependent neutronics/thermal-hydraulics solution for gas reactors
  - Benchmarked with Julich SANA Test Experimental Data and OECD PBMR-400 Benchmark [Seker, 2007]

- **GENPMAXS** - **GEN**erates **PMAXS** cross section files for PARCS
  - Reads SCALE/TRITON output at all burnup and temperature/fluid conditions and provides cross section library for PARCS

PARCS LWR Code Assessment (Partial List)

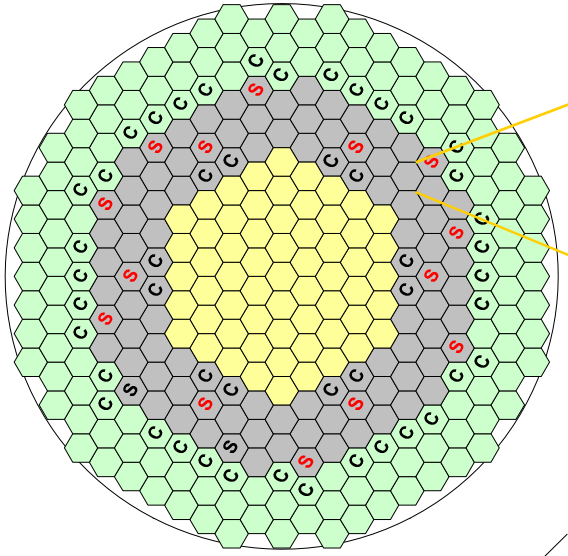
- Stand-alone Neutronics Tests
  - NEACRP-L336 Pin Benchmark
  - NEACRP PWR Rod Ejection/Withdrawal Benchmarks
  - VVER1000 Rod Ejection Benchmark
  - VENUS-2 Critical Benchmark
  - OECD MOX Core Transient Benchmark

- Coupled Code Tests (TRACE/RELAP5/PARCS)
  - OECD PWR-MSLB Benchmark
  - OECD BWR PBTT BWR: Peach Bottom
  - BWR Ringhalls Stability
  - BWR: Peach Bottom Cycle 1 and 2 Depletion Benchmark

PARCS for HTR Analysis

- PARCS Neutronics Methods
  - PBR
  - PMR
- Hexagon TPEN Solution Kernel
  - Implementation
  - Verification/Validation
- Cylindrical FMFD Solution Kernel
  - Implementation
  - Verification/Validation

Prismatic VHTR Core

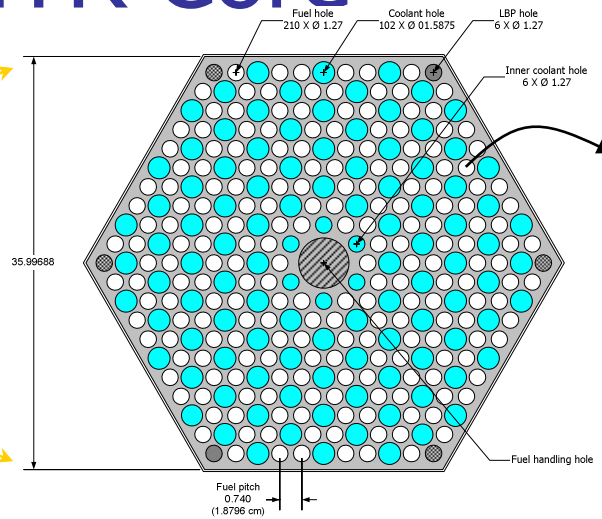


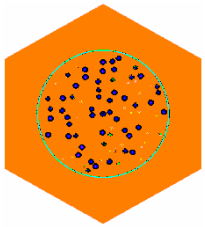
Active Core

Inner reflector

Outer reflector

C and S denote control and reserved shutdown rods

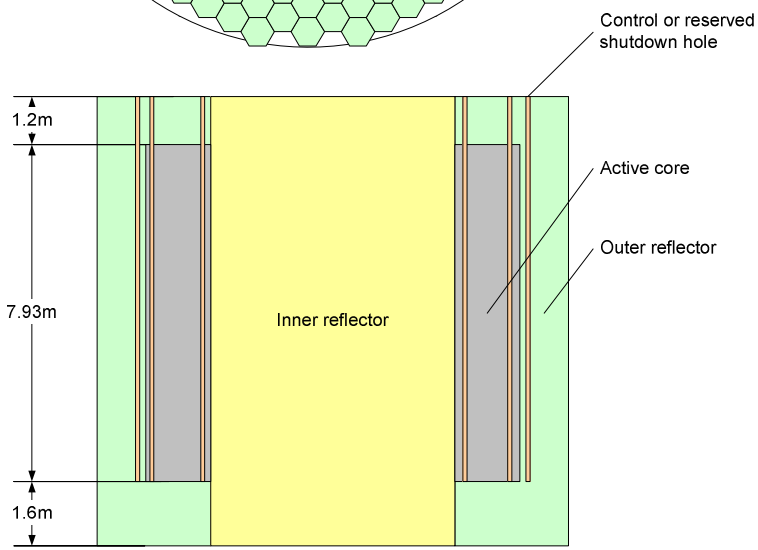




Fuel pin cell

Coolant hole

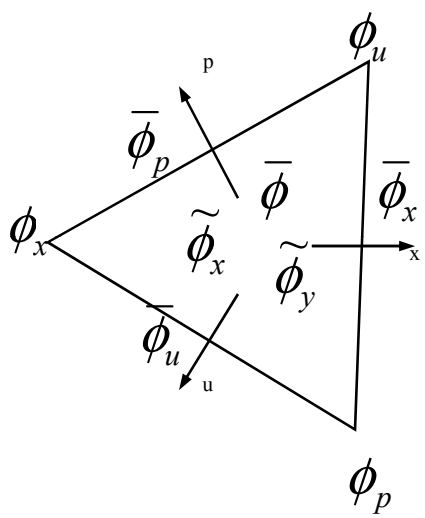
Fuel compact



- **Characteristics**
  - **Annular core design**
    - **Fuel blocks (3 rings) surrounded by Inner reflector (5 rings) and outer reflector (3 rings)**
  - **Fuel Compact with TRISO particles (double heterogeneity)**

PARCS Hexagonal Nodal Method: Triangular Polynomial Expansion Formulation

- Unknowns Selected for a Triangle (9 in total per Group)



  - Fluxes at three Corners, $\phi_d = \phi\ (r_d)$
  - Surface average fluxes at three surfaces

$$\bar{\phi}_x = \frac{1}{h}\int \phi\ (x,y)\, dy$$

  - Moments

$$\tilde{\phi}_x = \frac{2\sqrt{3}}{3h}\frac{1}{V}\iint x\phi\ (x,y)\, dydx \qquad \tilde{\phi}_y = \frac{2}{h}\frac{1}{V}\iint y\phi\ (x,y)\, dydx$$

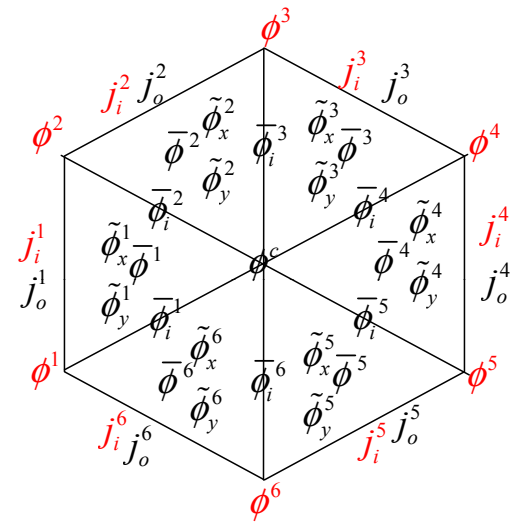
  - Nodal Volume Average Flux, $\bar{\phi} = \frac{1}{V}\iint \phi\ (x,y)\, dydx$

- Flux Expansion for a Triangle

$$\phi(x,y) = c_0 + a_x x + a_y y + b_x x^2 + b_u u^2 + b_p p^2 + c_x x^3 + c_u u^3 + c_p p^3$$

System of TPEN Equations for Single Hexagon Problem

$$
\begin{bmatrix}
A_1 & 0 & 0 & A_2 & A_3 & A_4 & A_5 & 0 & 0 & 0 \\
0 & X_1 & 0 & X_2 & X_3 & X_4 & X_5 & 0 & 0 & 0 \\
0 & 0 & Y_1 & Y_2 & 0 & 0 & 0 & 0 & 0 & 0 \\
S_1 & S_2 & S_3 & S_4 & 0 & S_5 & 0 & 0 & 0 & 0 \\
C_1^R & C_2^R & 0 & 0 & C_3^R & C_4^R & 0 & 0 & 0 & 0 \\
0 & P_1 & 0 & 0 & P_2 & P_3 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & C_2^Z & C_3^Z & C_4^Z & C_5^Z \\
0 & 0 & 0 & 0 & Z_1^F & 0 & Z_2^F & Z_3^F & 0 & 0 \\
0 & 0 & 0 & 0 & Z_1^S & 0 & Z_2^S & 0 & Z_4^S & Z_5^S \\
I_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -6
\end{bmatrix}
\begin{bmatrix}
\bar{\phi} \\ \tilde{\phi}_x \\ \tilde{\phi}_y \\ \bar{\phi}_i \\ \bar{J}_o^R \\ \phi^c \\ \bar{J}_o^Z \\ \tilde{\phi}_z^F \\ \tilde{\phi}_z^S \\ \bar{\phi}
\end{bmatrix}
=
\begin{bmatrix}
\bar{S} \\ \tilde{S}_x \\ \tilde{S}_y \\ \bar{S}_i \\ \bar{S}_o^R \\ S^c \\ \bar{S}_o^Z \\ \tilde{S}_z^F \\ \tilde{S}_z^S \\ 0
\end{bmatrix}
$$



$$A_1 = X_1 = Y_1 = \frac{80D}{h^2} I_6, \quad A_2 = -\frac{32D}{h^2} J_6, A_3 = -\frac{64D}{h^2} I_6, A_4 = \frac{16D}{3h^2} e_6, A_5 = \frac{1}{h_Z} f_6,$$

$$X_2 = \frac{8D}{3h^2} J_6, X_3 = -\frac{32D}{3h^2} I_6, X_4 = \frac{16D}{9h^2} e_6, X_5 = -\frac{1}{54h_Z} f_6, Y_2 = \frac{8D}{h^2} K_6,$$

$$S_1 = -10J_6', S_2 = 30J_6', S_3 = 30K_6', S_4 = 24I_6, S_5 = -e_6,$$

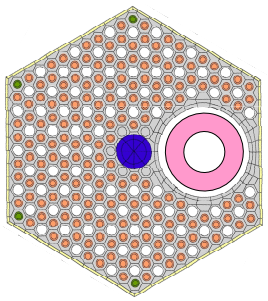
$$C_1^R = -\frac{20\sqrt{3}D}{3h} I_6, C_2^R = -\frac{40\sqrt{3}D}{h} I_6, C_3^R = \left(1 + \frac{16\sqrt{3}D}{h}\right) I_6, C_4^R = -\frac{2\sqrt{3}D}{3h} e_6,$$

$$P_1 = 15e_6', P_2 = -2e_6', P_3 = 6,$$

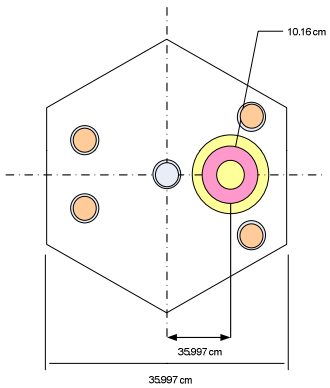
$$J_6 = \begin{bmatrix} 1 & 1 & & & & \\ & 1 & 1 & & & \\ & & 1 & 1 & & \\ & & & 1 & 1 & \\ & & & & 1 & 1 \\ 1 & & & & & 1 \end{bmatrix}, K_6 = \begin{bmatrix} 1 & -1 & & & & \\ & 1 & -1 & & & \\ & & 1 & -1 & & \\ & & & 1 & -1 & \\ & & & & 1 & -1 \\ -1 & & & & & 1 \end{bmatrix}, e_6 = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}, f_6 = \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$$

Prismatic HTR Core: Control Rod

- Characteristics
  - Large local flux variation near core-reflector interface
  - Control rod loading in one-sixth sector of reflector and fuel blocks

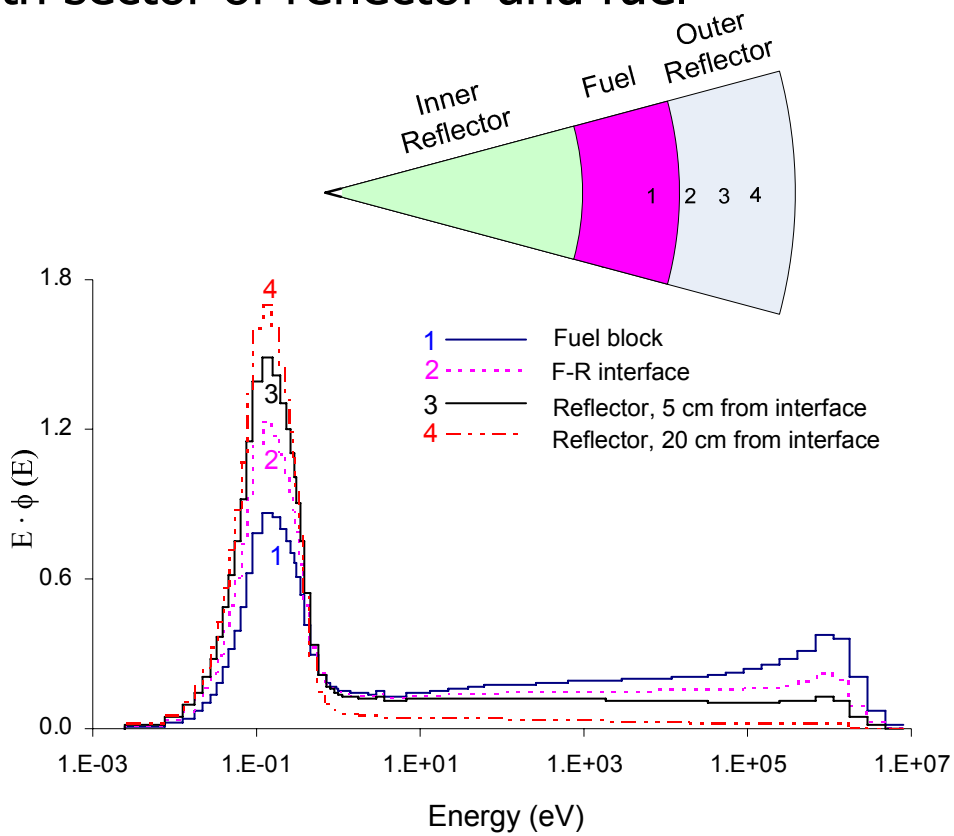


Fuel



Reflector

(Control rod design)

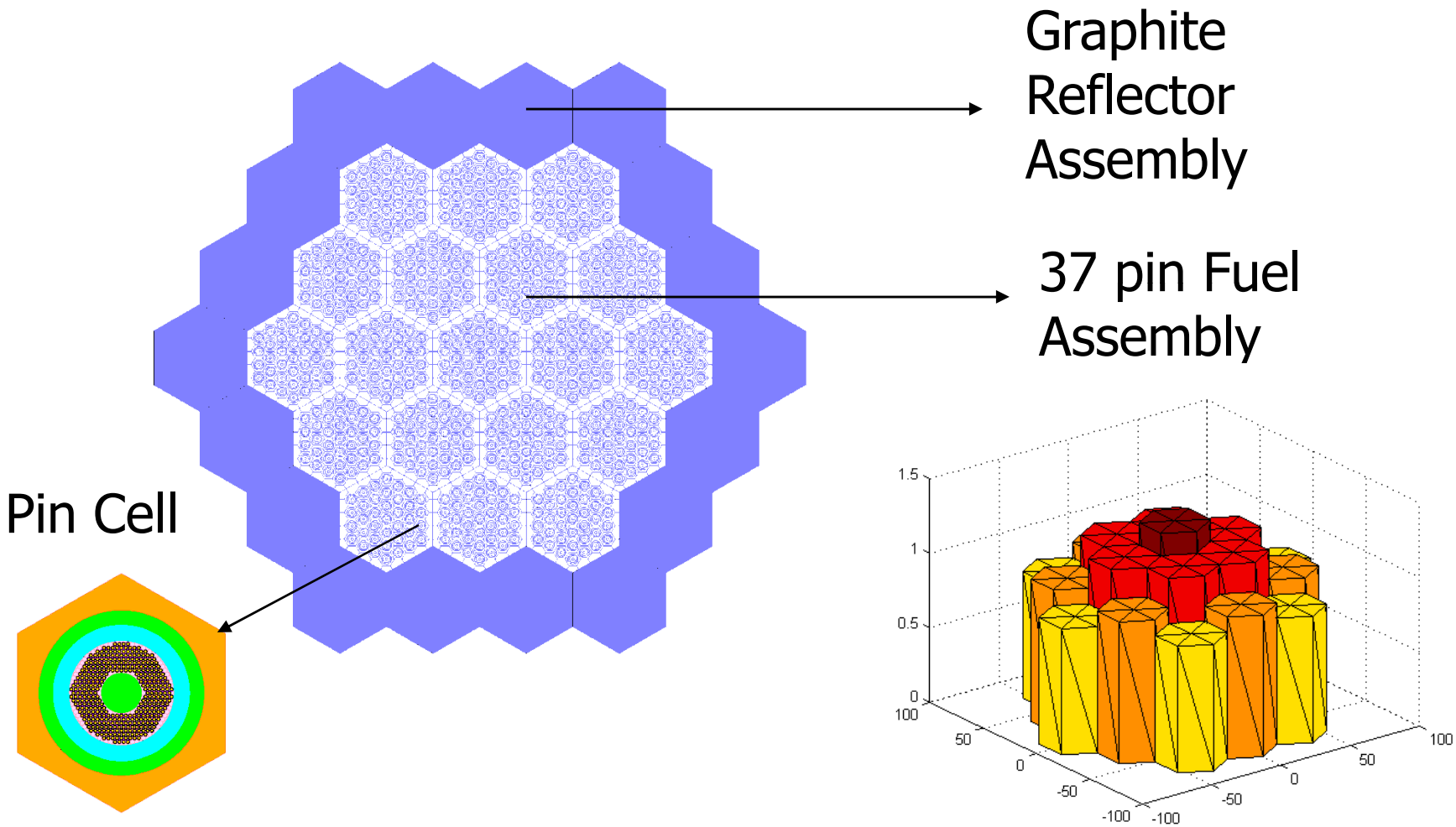


Preliminary Validation of PARCS for Prismatic HTR

- Perform "4 Ring" Mini-Core (2D) calculation with PARCS using 2-group (3.059ev thermal cutoff) xsecs generated with HELIOS

- Compared result with MCNP5 with explicit representation of fuel compacts in each pin cell
  - 500K hst/cycle x 300 cycles = 15 M histories
  - Tallies in each of 19 fuel assemblies

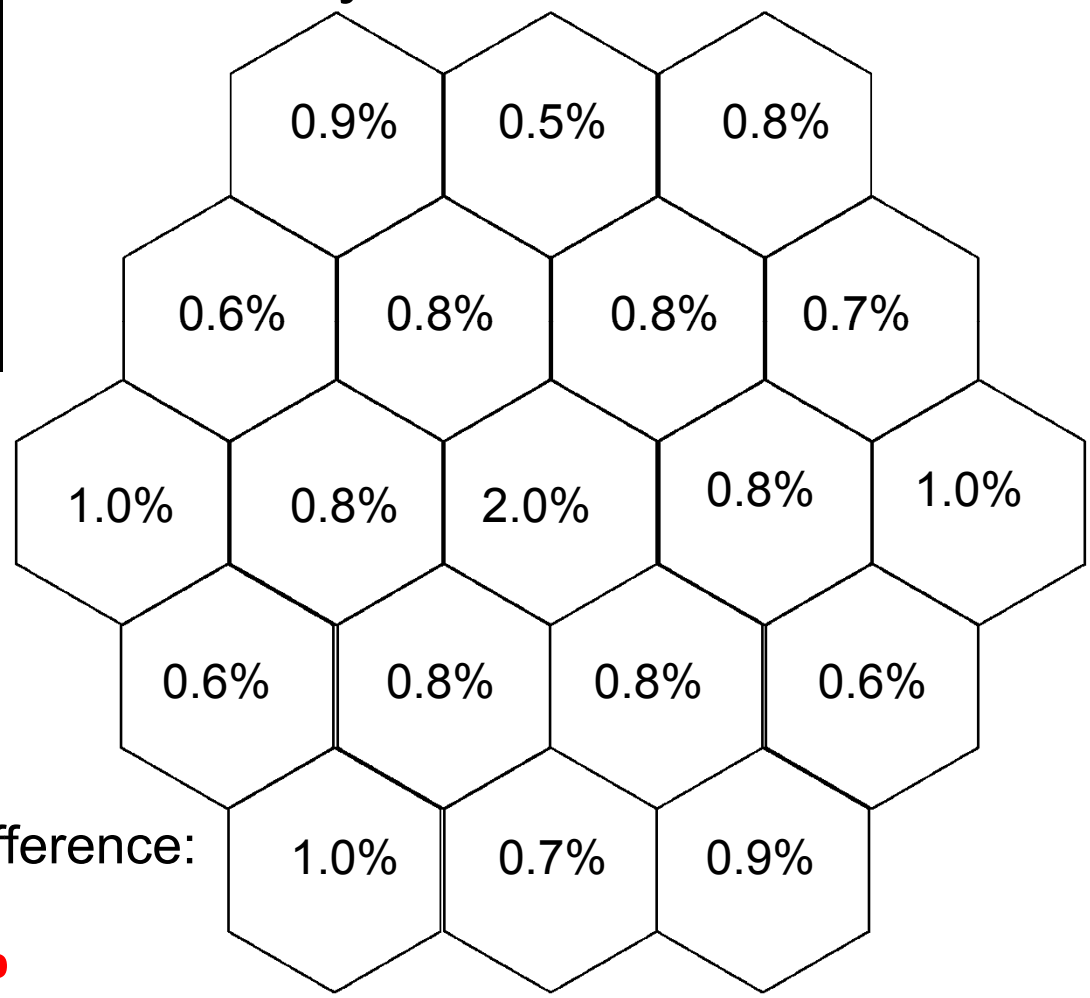
HTTR Mini Core Calculation with PARCS



PARCS vs MCNP Comparison

	k_∞
MCNP	1.11217 (± 0.00007)
PARCS	1.11155 **(- 62 pcm)**

Assembly Power %Difference

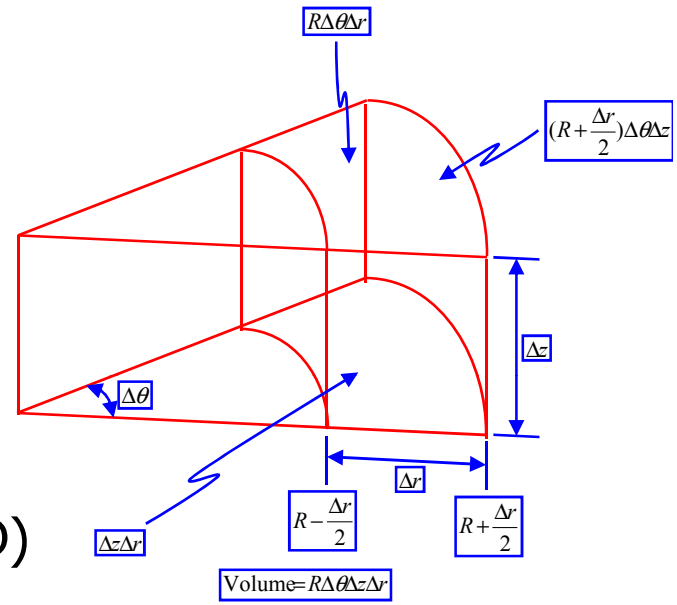


RMS Power Difference:

0.91%

PARCS for PBMR: Cylindrical Geometry

- Funded by U.S. NRC in 2004
- Capability for Cylindrical Geometry
  - Diffusion and SP3, Multi-group
  - Steady State, Transient
- Framework
  - Fine mesh FDM + Acceleration (CMR, CMFD)
  - Kernel : FDM, FMFD



$$\frac{1}{v_g}\frac{d\phi_g}{dt}=\frac{\chi_{pg}}{k_{eff}}\sum_{g=1}^{G}\nu_{pg}\Sigma_{fg}\phi_g+\chi_{dg}\sum_{k=1}^{K}\lambda_k C_k+\sum_{g'=1(g'\neq g)}^{G}\Sigma_{sg'g}\phi_{g'}-\Sigma_{tg}\phi_g+\nabla.D_g\nabla\phi_g$$

Validation of PARCS for the PBMR:

THE OECD PBMR STEADY STATE AND COUPLED KINETICS CORE THERMAL-HYDRAULICS BENCHMARK TEST PROBLEMS

Frederik Reitsma PBMR Ltd, South Africa

Gerhard Strydom [1], Han de Haas [2], Kostadin Ivanov [3], Bismark Tyobeka [3],
Ramatsemela Mphahlele [3*], **Tom Downar [4], Volkan Seker** [4], Hans D Gougar [5], D F Da Cruz [2]

[1] Reactor Analysis Group, PBMR (Pty) Ltd, South Africa
[2] Fuel, Actinides & Isotopes Group, NRG, The Netherlands
[3] Nuclear Engineering Program, Penn State University, USA
[4] Nuclear Engineering Department, Purdue University, USA
[5] Fission & Fusion Systems, INEEL, USA
[*] National Nuclear Regulator, Centurion, South Africa

The Second Topical Meeting on High Temperature Reactor 2004
September 22-24, 2004
Beijing, China

Validation of PARCS for PBMR

- PBMR-400
  - Graphite Moderated, Helium Cooled
  - 400MW$_{th}$
  - 500-900°C (gas in-out)
  - Solid Central Reflector
  - 2 GRP XSECS Provided

	0	10	41	73.6	80.55	92.05	100	117	134	151	168	185	192.95	204.45	211.4	225	243.6	260.6	275	287.5	292.5	310	328	462	463
-235		10	31	32.6	6.95	11.5	7.95	17	17	17	17	17	7.95	11.5	6.95	13.6	18.6	17	14.4	12.5	5	17.5	18	134	1
-200	35	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	TP	He	RPV	Air	RCCS
-150	50	CC	CC	CC	CC	RSS	CC	TR	TR	TR	TR	TR	SR	RCS	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
-100	50	CC	CC	CC	CC	RSS	CC	TR	TR	TR	TR	TR	SR	RCS	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
-50	50	CC	CC	CC	CC	RSS	CC	TR	TR	TR	TR	TR	SR	RCS	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
0	50	CC	CC	CC	CC	RSS	CC	V	V	V	V	V	SR	RCS	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
50	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	IP	RCS	IP	IP	IP	RC	SR	He	CB	He	RPV	Air	RCCS
100	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
150	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
200	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
250	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
300	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
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550	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
600	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
650	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
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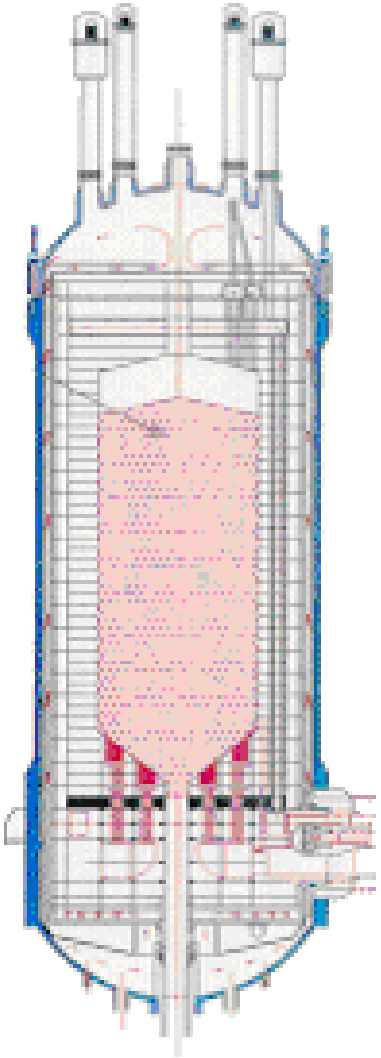
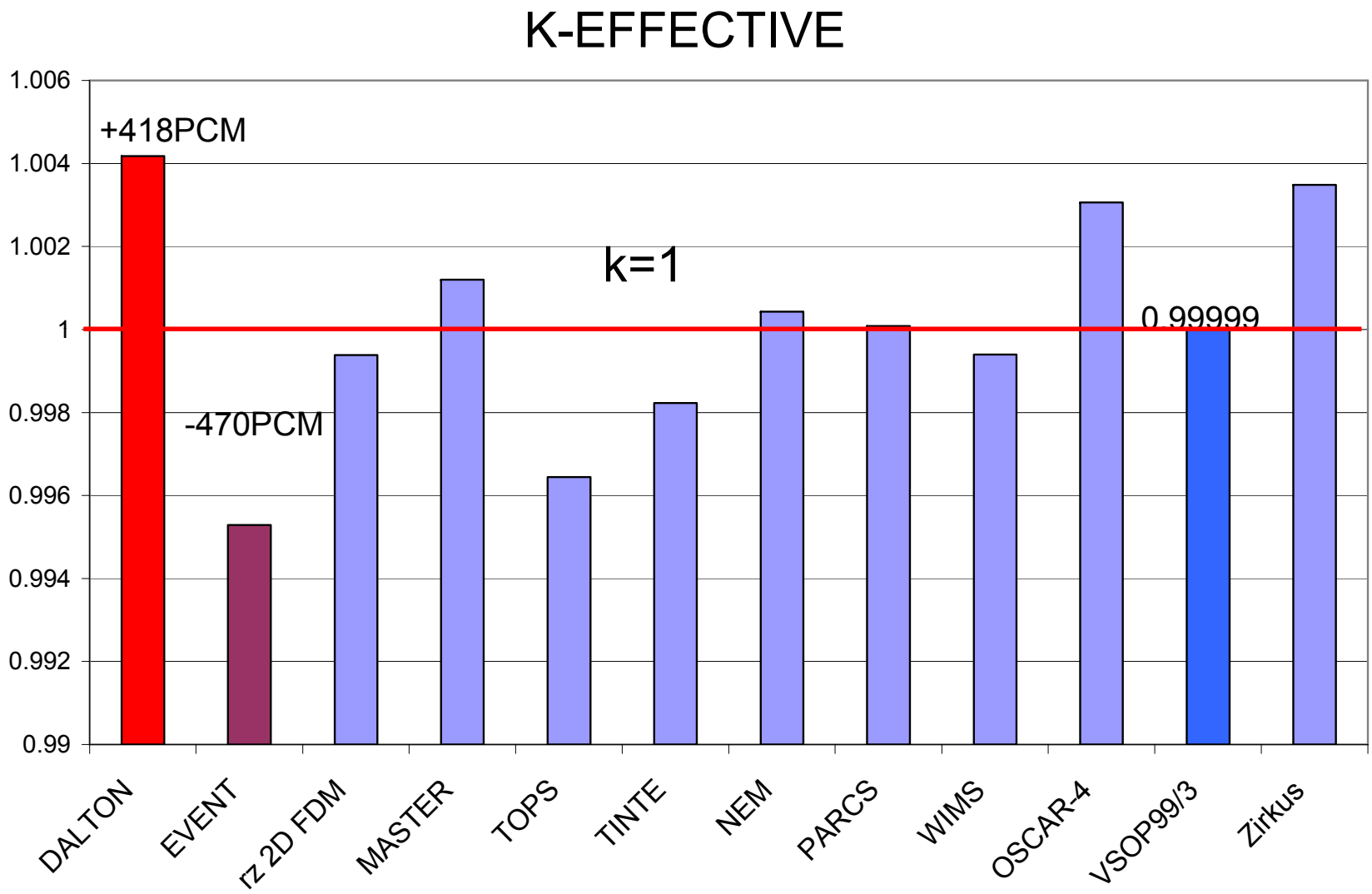
1000	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1050	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1100	50	CC	CC	CC	CC	RSS	CC	F	F	F	F	F	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1150	50	CC	CC	CC	CC	RSS	CC	BR	BR	BR	BR	BR	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1200	50	CC	CC	CC	CC	RSS	CC	BR	BR	BR	BR	BR	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1250	50	CC	CC	CC	CC	RSS	CC	BR	BR	BR	BR	BR	SR	RCS	SR	SR	SR	RC	SR	He	CB	He	RPV	Air	RCCS
1300	50	CC	CC	CC	CC	CC	CC	BR	BR	BR	BR	BR	SR	SR	SR	SR	SR	IP	SR	He	CB	He	RPV	Air	RCCS
1350	50	CC	CC	CC	CC	CC	CC	BR	BR	BR	BR	BR	SR	SR	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
1400	50	CC	CC	CC	CC	CC	CC	OP	OP	OP	OP	OP	SR	SR	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
1450	50	CC	CC	CC	CC	CC	CC	BR	BR	BR	BR	BR	SR	SR	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
1500	50	CC	CC	CC	CC	CC	CC	BR	BR	BR	BR	BR	SR	SR	SR	SR	SR	SR	SR	He	CB	He	RPV	Air	RCCS
1535	35	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	BP	He	RPV	Air	RCCS



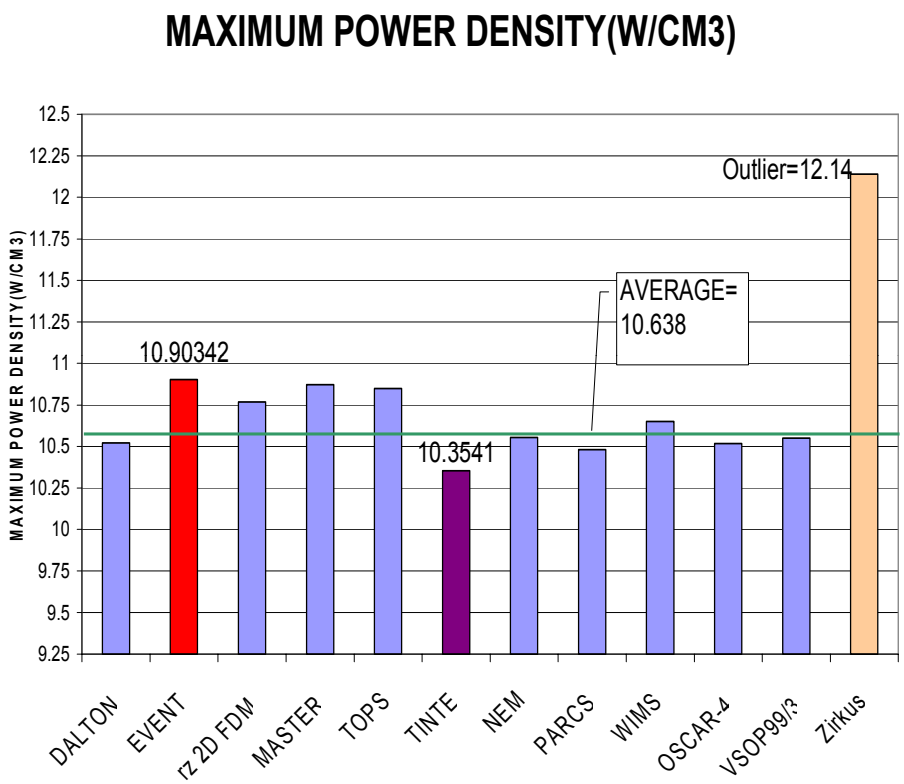
- STEADY STATE BENCHMARK CALCULATIONAL CASES
  - **CASE S-1**: Neutronics Solution with Fixed Cross Sections
  - **CASE S-2**: Thermal Hydraulic solution with given power / heat sources
  - **CASE S-3**: Combined neutronics thermal hydraulics calculation – starting condition for the transients

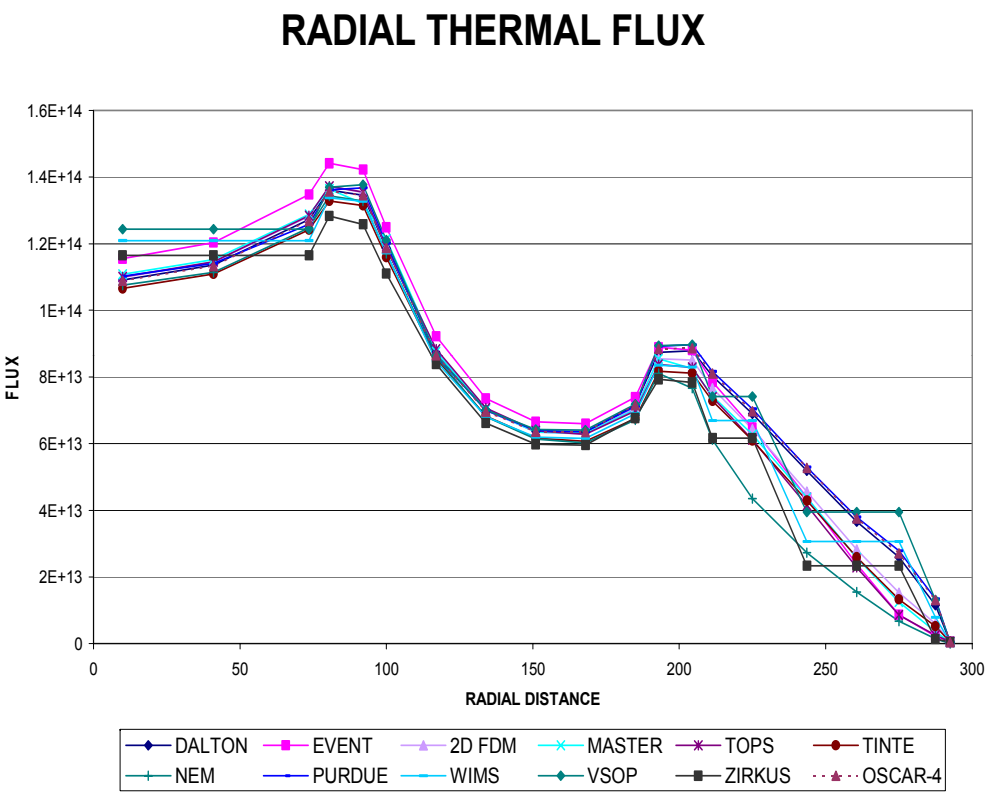
- TRANSIENT BENCHMARK CALCULATIONAL CASES
  - **CASE T-1**: Depressurised Loss of Forced Cooling (DLOFC) w/o SCRAM
  - **CASE T-2** : DLOFC with SCRAM
  - **CASE T-3** :Pressurised Loss of Forced Cooling (PLOFC) with SCRAM
  - **CASE T-4** : 100-40-100 Load Follow
  - **CASE T-5** : Reactivity Insertions by CRE
  - **CASE T-6** : Cold Helium Inlet

Exercise 1 Results
Neutronics w/ Fixed Cross Sections



Exercise 1 Results (cont.)





Interface Between SCALE/TRITON and PARCS: GENPMAXS

$$\Sigma(C,S,N,H) = \sum_{i=0}^{Nc} c_i \Sigma_i (S,N,H)$$

$$\Sigma_i (S,N,H) = \Sigma^r (H) + \Delta\Sigma_i^{CR}(H) + \sum_{j=2}^{Ns} \Delta s_j \left.\frac{\partial \Sigma_i}{\partial s_j}\right|_{(S_j^m, N^r, H)}$$

$$+ \sum_{j=1}^{4} \left(\sum_{k=1}^{Nn} n_{j,k} \left.\frac{\partial \Sigma_i}{\partial n_k}\right|_{\left(S, N_{j,k}^m, H\right)} \right)$$

C={c_1, c_2, …} : fractions for each type of CR;

S={S_2, S_3, …,S_{10}}={Dc,Pc,Tf,Tc,Ic,Dm,Pm,Tm,Im}: state variables of current node

N: state value differences between neighbors and current nodes

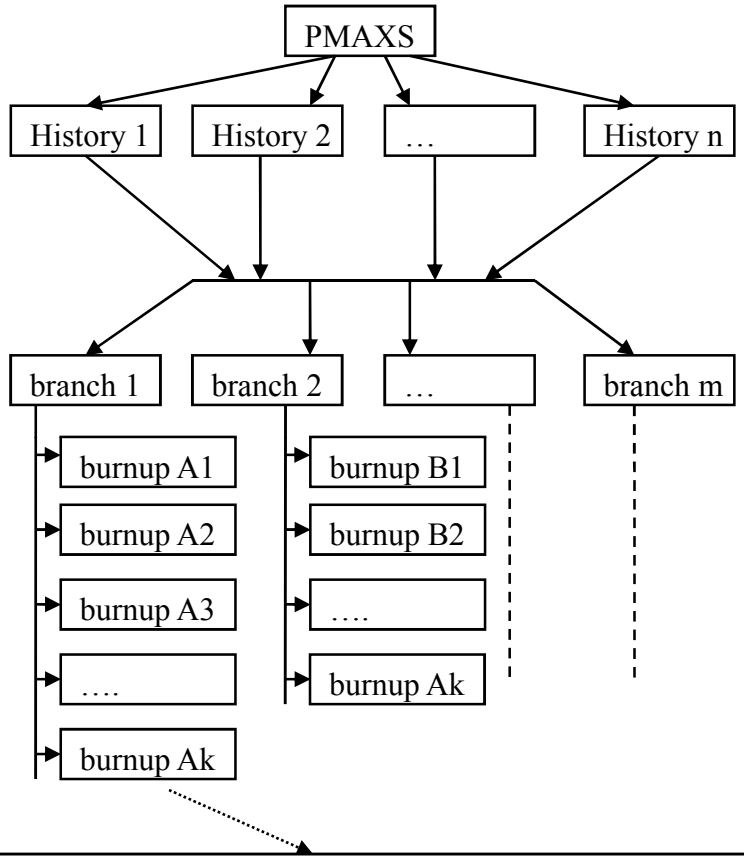
H: history variables (burnup, control rod history, coolant density history, etc.

PMAXS File Content

			Existence
1	XS Control Information		Always
2	Branches Information		Optional
3	Burnup Information		PMAXS
XS Set/(History case) wise data			Always
4	XS Set identification		Always
5	History case identification		PMAXS
6	T/H invariant variable block(repeat for burnup)		Always
	6.1	Chi, Chid, inV, Det	Optional
	6.2	Yield	Optional
	6.3	CDF	Optional
	6.4	Group-wise form function	Optional
	6.5	Beta of Delayed neutron	Optional
	6.6	Lambda of Delayed neutron	Optional
	6.7	Decay heat data	Optional
	Reference state data		Always
7	State identification		Always
8	XS Data Block (repeated for burnup points)		Always
	8.1	Principal cross sections (tr,ab,nf,kf,fi,chi,inv,xe,sm)	Always
	8.2	Scattering cross sections	Always
	8.3	ADF	Optional
	8.4	Direct energy deposition and J1 factors	Optional
	Ith type branches (same structure with Ref. state case)		NBR(i)>0

*The data in XS Block are original data for reference state, and partials for other branches

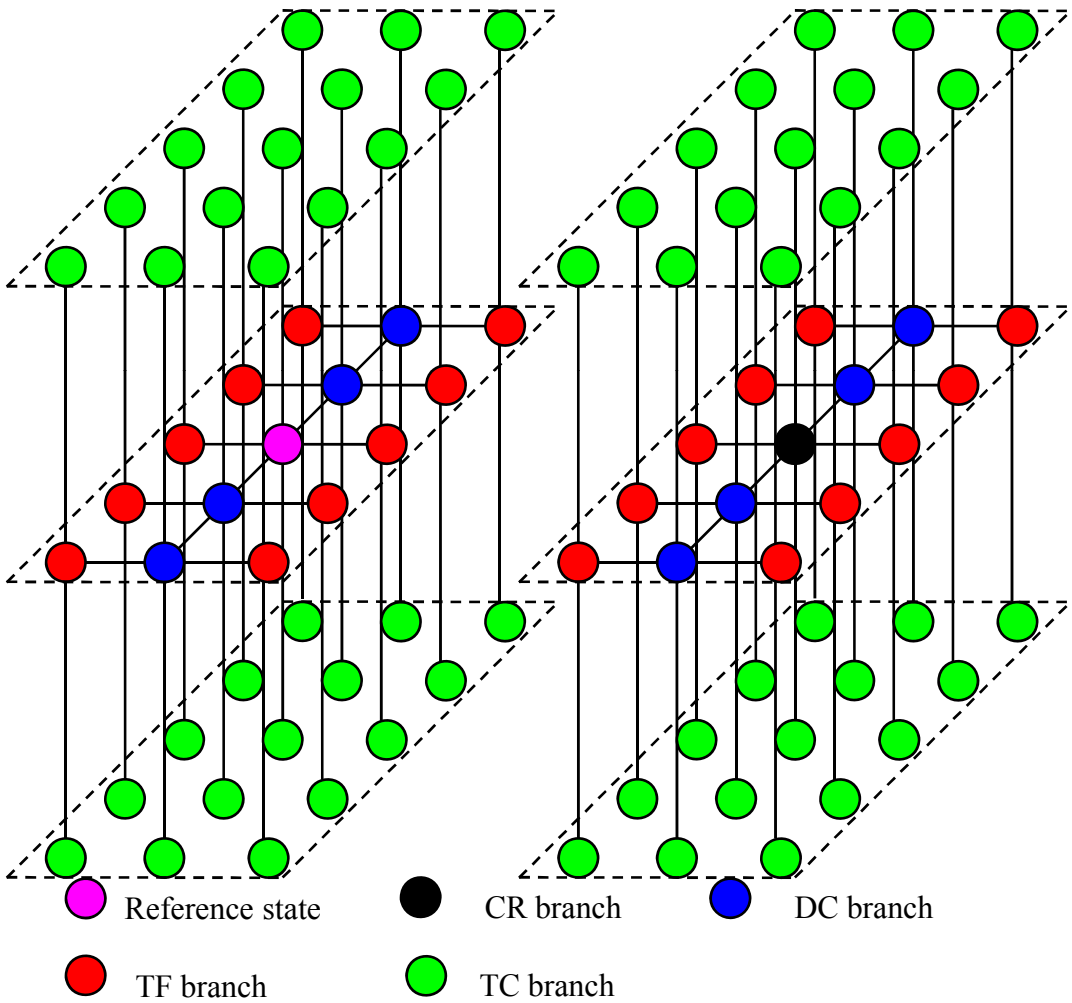
PMAXS Data Structure



$$\Sigma_{tr}(1:G), \Sigma_a(1:G), \nu\Sigma_f(1:G), \chi(1:G), \Sigma_s(g'->g), ADFs$$
$$\kappa\Sigma_f(1:G), \Sigma_f(1:G), \sigma_a^{Sm}(1:G), \sigma_a^{Xe}(1:G), Y_I, Y_{Xe}, Y_{Pm}$$
$$CDFs, PFF, \sigma_{\det}, 1/v, \beta, \lambda, \beta_{decayheat}, \lambda_{decayheat},$$

- PMAXS contains 1 or more history cases. Data points with same history values (except burnup) form a history case.
- Every History contains same number of branches. Data points with same instantaneous state values form a branch.
- Each branch contains 1 or more burnup points which may different for different branches.
- Each burnup points contains cross sections listed in the block at bottom of picture

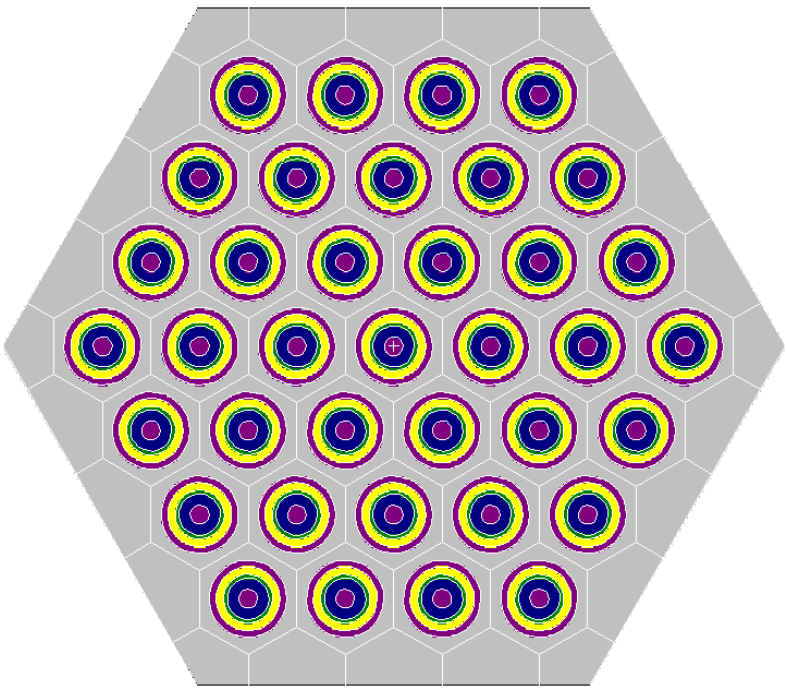
PMAXS with Multi-Dimensional Table Data Points



- 90 data points:
  - 1 reference state
  - 1 CR branch
  - 8 DC branches
  - 20 TF branches
  - 60 TC branches
- At most 30 points can be involved in evaluating XS at given condition for PMAXS model, while at most 16 points can be involved for piece-wise linear interpolation model

TRITON/PARCS Test Problem

A simplified HTTR assembly was modeled with SCALE to generate a set cross section for PARCS.



Energy Group Structure

- 2 group: 3.059 eV
- 4 group: 0.624eV – 3.059eV – 9119 eV

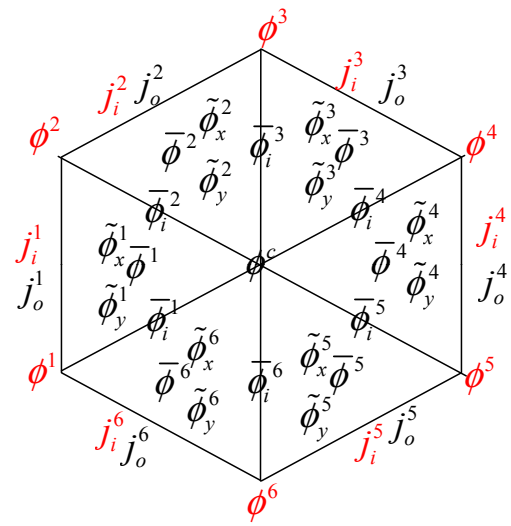
Burnup Branch

- 50 + 17*100 days = 1750 Days
- 30MW core power (HM loading from JAERI HTTR document)

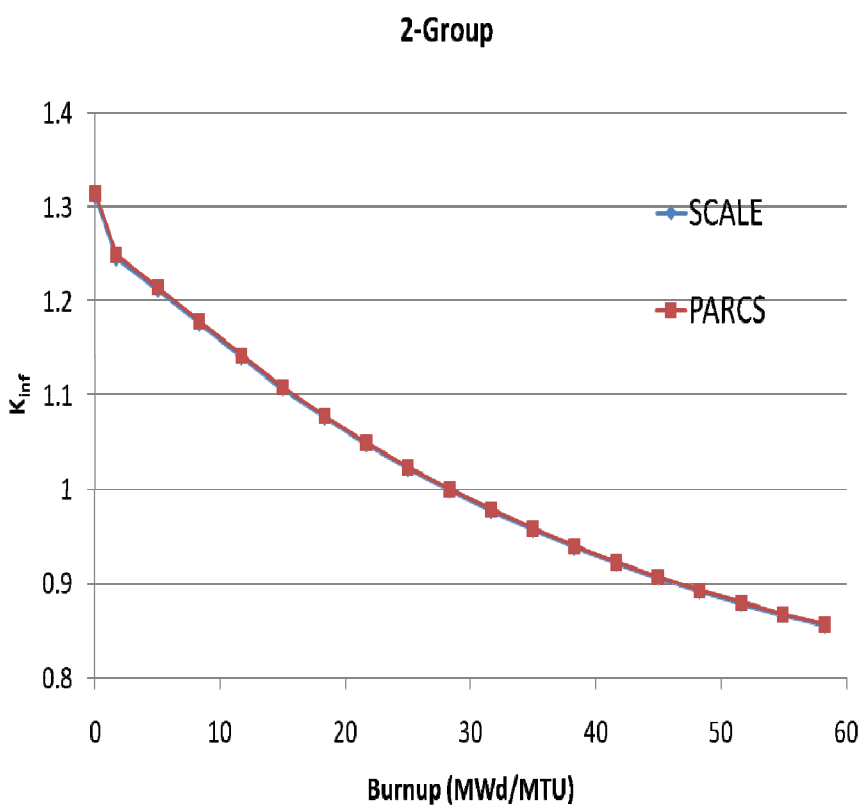
Two sets of PMAXS files were generated by GENPMAXS (2 GRP and 4 GRP)

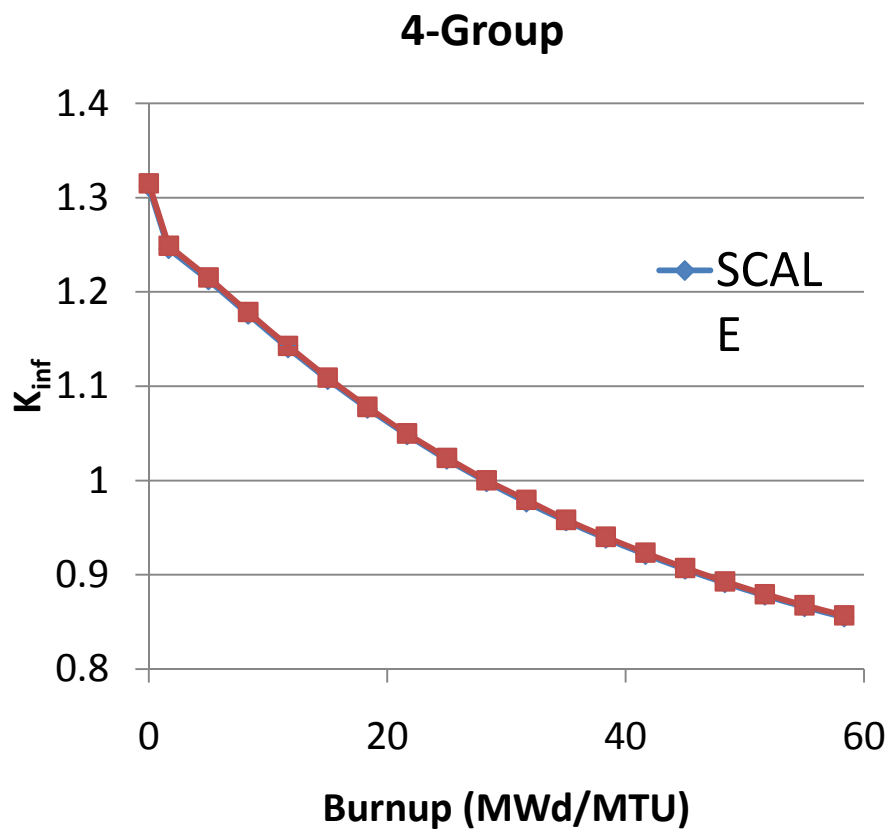
PARCS Model

- A single assembly model with reflective boundary conditions was generated.
- PARCS Macro-Depletion option was turned on.
- TPEN kernel is used to solve the hexagonal geometry diffusion problem.



Validation Results





Summary

- A meeting was held at ORNL in January to formulate a roadmap for continued development and benchmarking of SCALE-TRITON/PARCS
- Preliminary Validation has been performed for the GENPMAXS Interface between SCALE(TRITON) and PARCS
- Preliminary Validation has been performed for the PARCS Cylindrical and Hexagonal Kernels. Work is continuing on investigation of improved kernels for the HTR.
- Work is continuing on the development and benchmarking of PARCS-AGREE for transient applications