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"Digital Nuclear Reactor" Data Storage Toolkit

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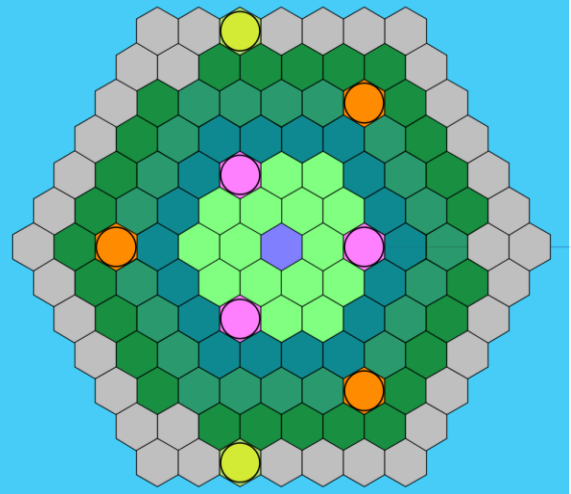
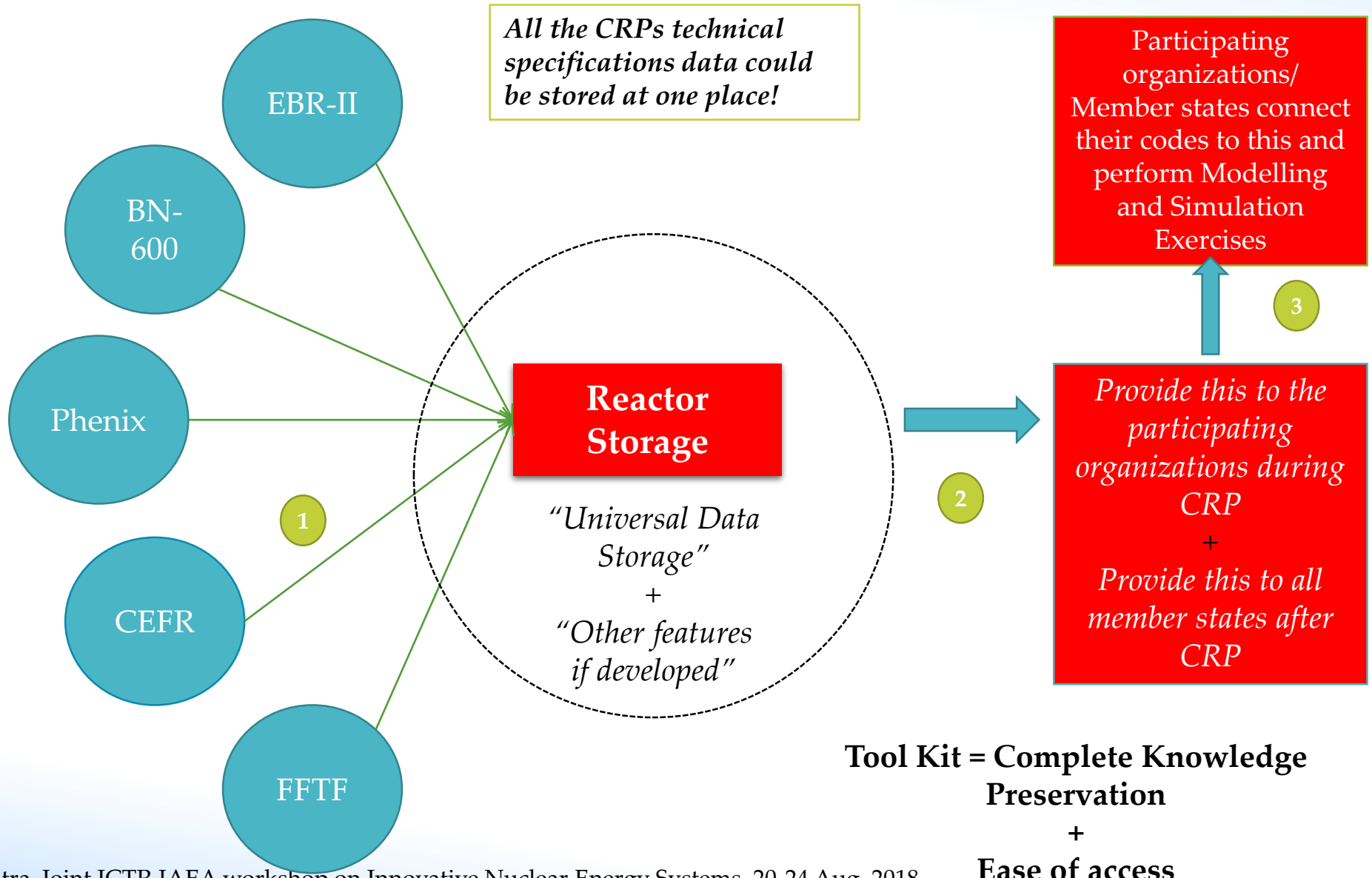


IAEA Benchmark in Digital Format?



Tool Kit = Complete Knowledge Preservation
+
Ease of access

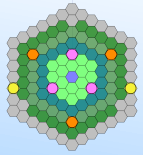
Objective and Features

Objective:

- The toolkit should provide a universal data storage system: an all-inclusive database with necessary reactor details required for modeling and numerical simulation.

Characteristic Features:

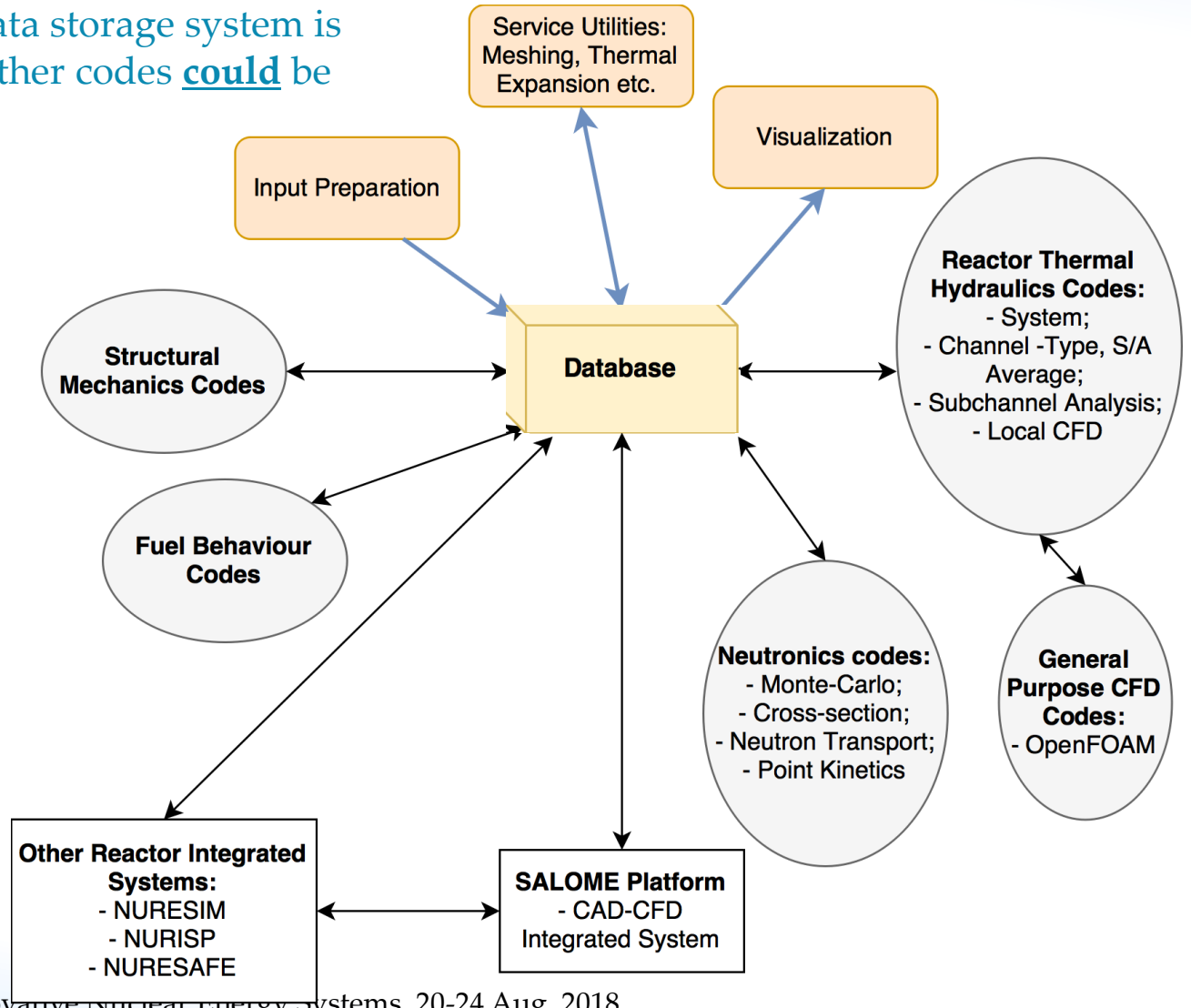
- **Store reactor data** in an hierarchical manner
- **Provides access to the stored reactor data** and a **standard interface for coupling** with the reactor simulation codes
- Bring simplicity in terms of code coupling
- **Visualize** the reactor geometry
- Basic meshing possibilities
- Thermal expansion
- Other features



Structure

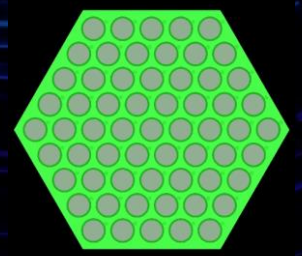
A central reactor data storage system is used and various other codes **could** be easily coupled

Various other utilities **could** be developed over it to support the modelling and simulation exercises



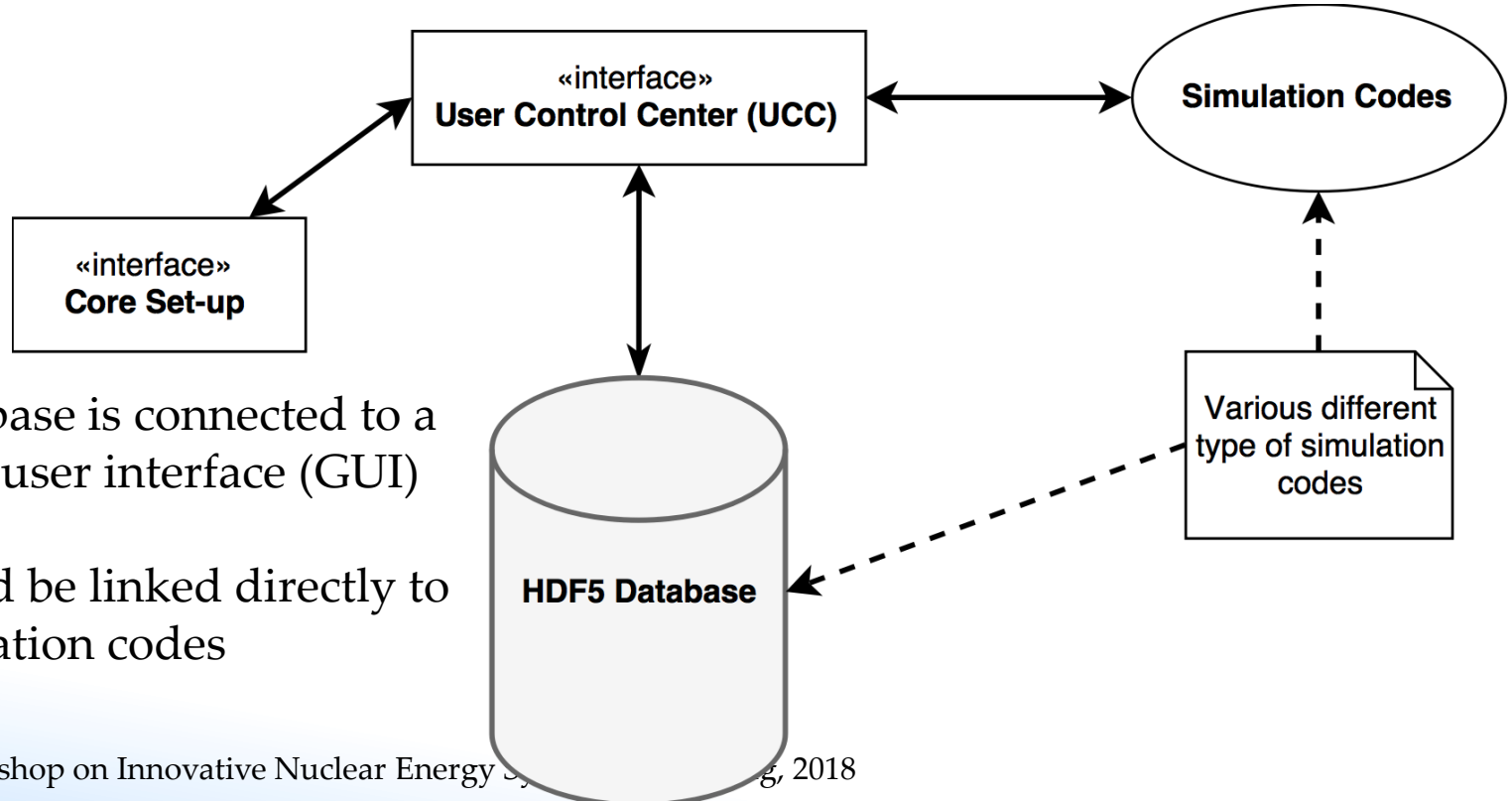
Data Exchange with
- Neutronics Codes
- Thermal-Hydraulic Codes
- Fuel Behavior Codes
- Structural Mechanics Codes
- Others

Understanding the Digital Nuclear Reactor Data Storage toolkit



Architecture

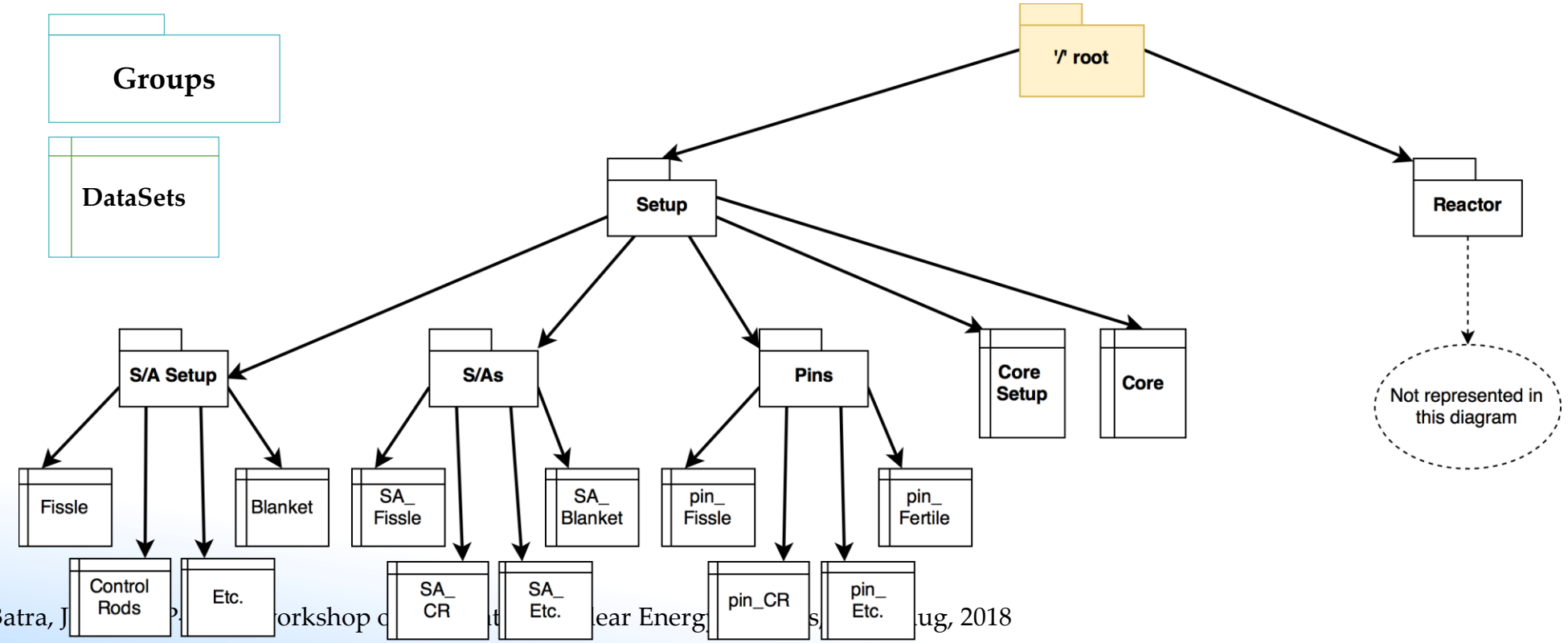
- **Database** chosen: Hierarchical Data Format (HDF)
- HDF could be used to store and organize a large amount of numerical data, which is the requirement of the toolkit
- Open source and compatible with different programming languages
- Data could be stored in a multidimensional space and be organized in the abstract manner



- The Database is connected to a graphical user interface (GUI)
- And could be linked directly to the simulation codes

HDF5 Structure based data storage

- Hierarchical storage of data - Based on the reactor structure
- An HDF5 file (object) can be considered as a container (group) that holds a variety of heterogeneous data objects (datasets)
- The data structure follows the very logic of the reactors
- *An intelligent database that understands the design philosophy of a reactor*

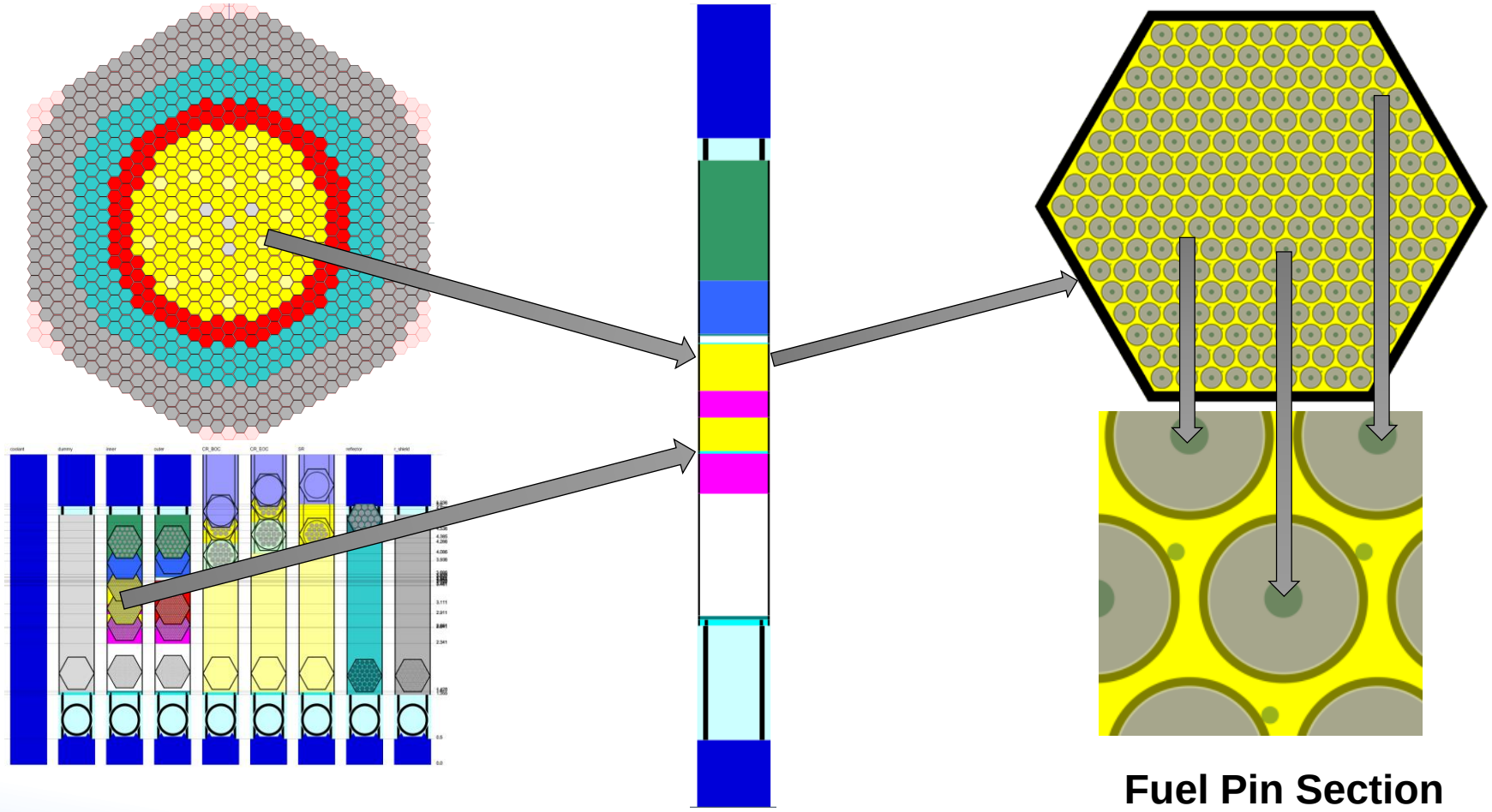


Basic Datasets

Set of S/As
describes full core structure

Axial S/A Layout
set of axial S/A Segments

S/A Segment
includes all fuel pins

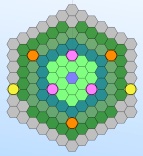


Fuel Pin Section

Visualization of Data Stored – from Pin to whole core

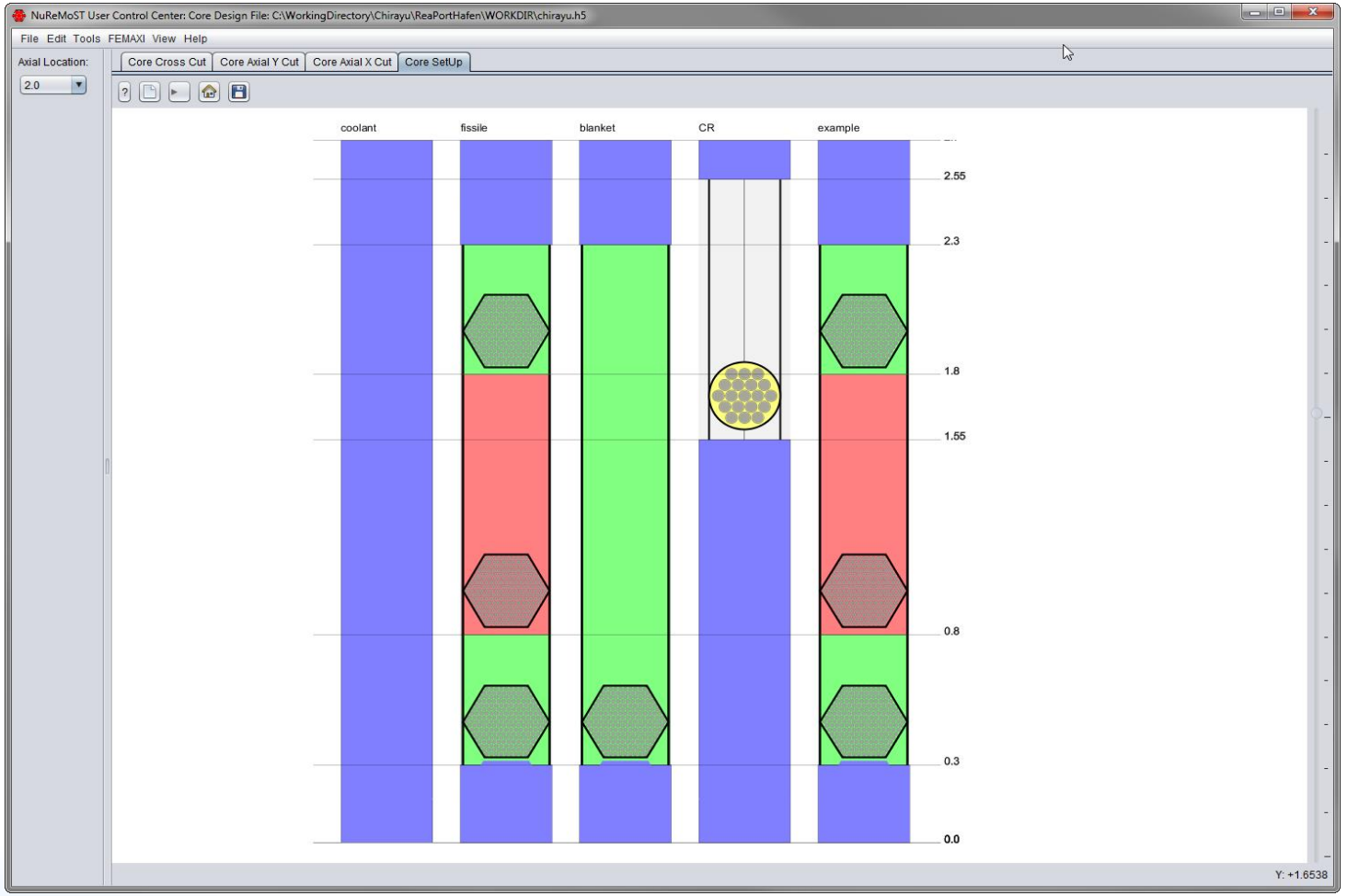
Integrated User Control Center iUCC

- Integrated User Control Center (iUCC)
- The toolkit has an inbuilt iUCC that aids in visualizations and provides graphical user interface for its applications
- The reactor setup file could be made with the iUCC enabled **graphical viewer**
- The structure of the setup file is made as explained in the previous slide
- The **data is broken into meaningful datasets** based on the parts of the reactor core, so that changes done at one part could easily be transferred up the hierarchy

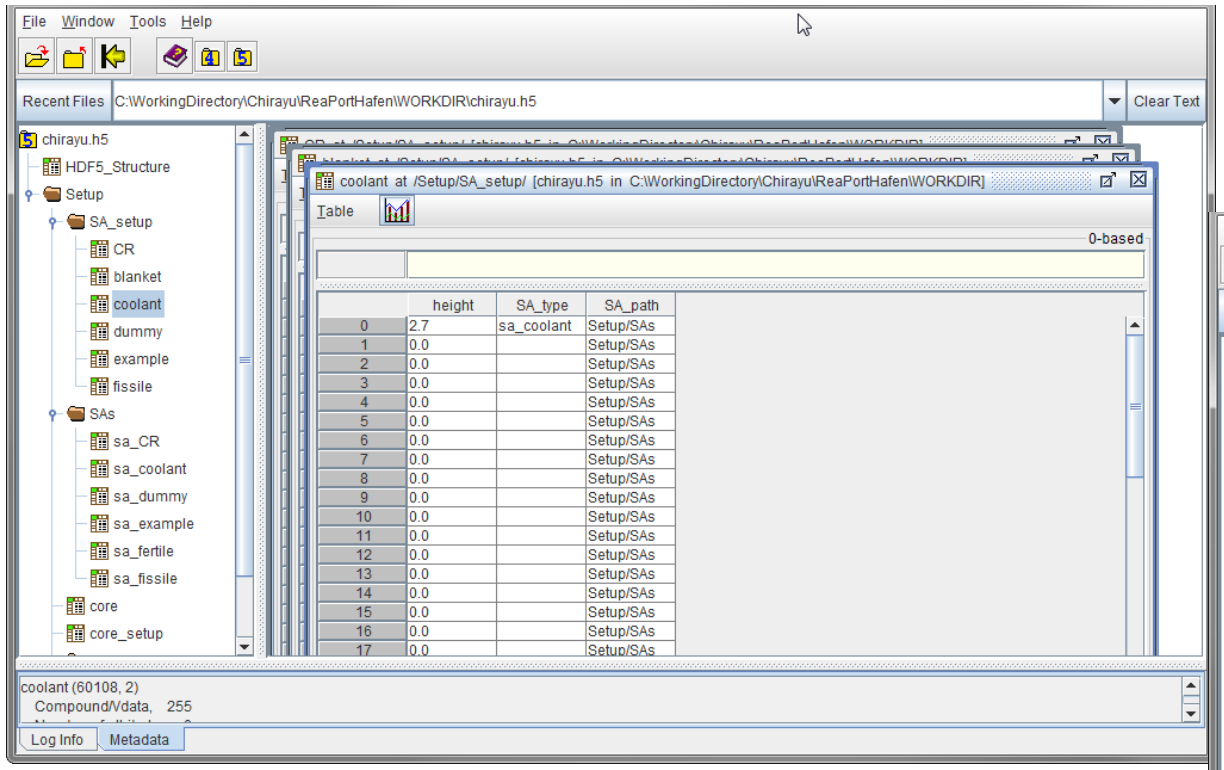


iUCC

- Starts with a basic set of template and could be modified graphically

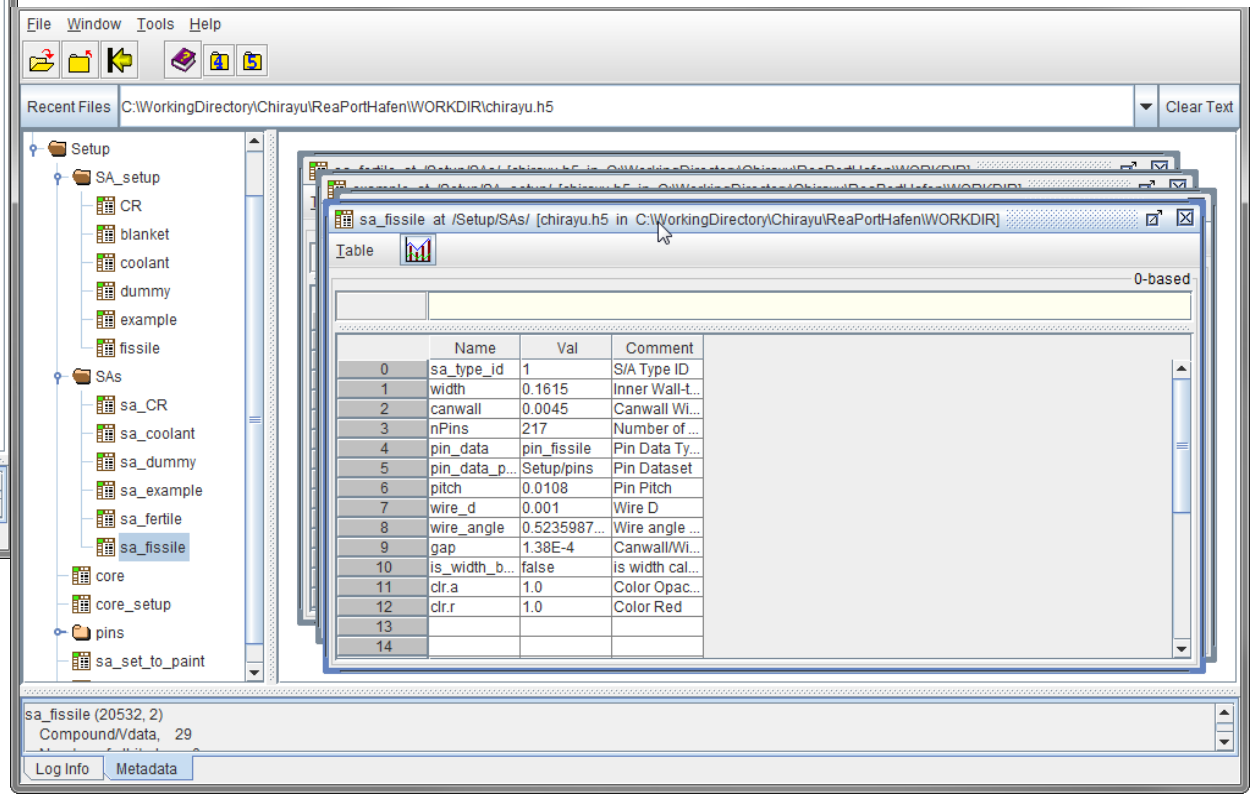


Data Input



HDF5 editor to input reactor data

- ✓ Data input is as simple as it is in excel file.
- ✓ Or copy and paste data from excel



Inserting data for the fissile subassembly

Example: NEW CRP:CEFR Start-up tests

- **Pre CRP:**

✓Storing all available data in the Digital Nuclear Reactor DST

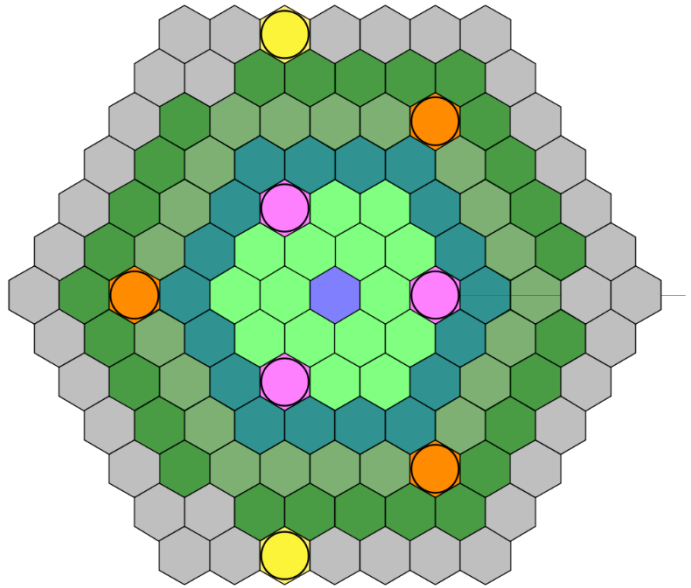
✓Evaluating the available data provided by CIAE

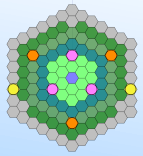
✓Requesting CIAE to provide more data/clarify for benchmark exercise

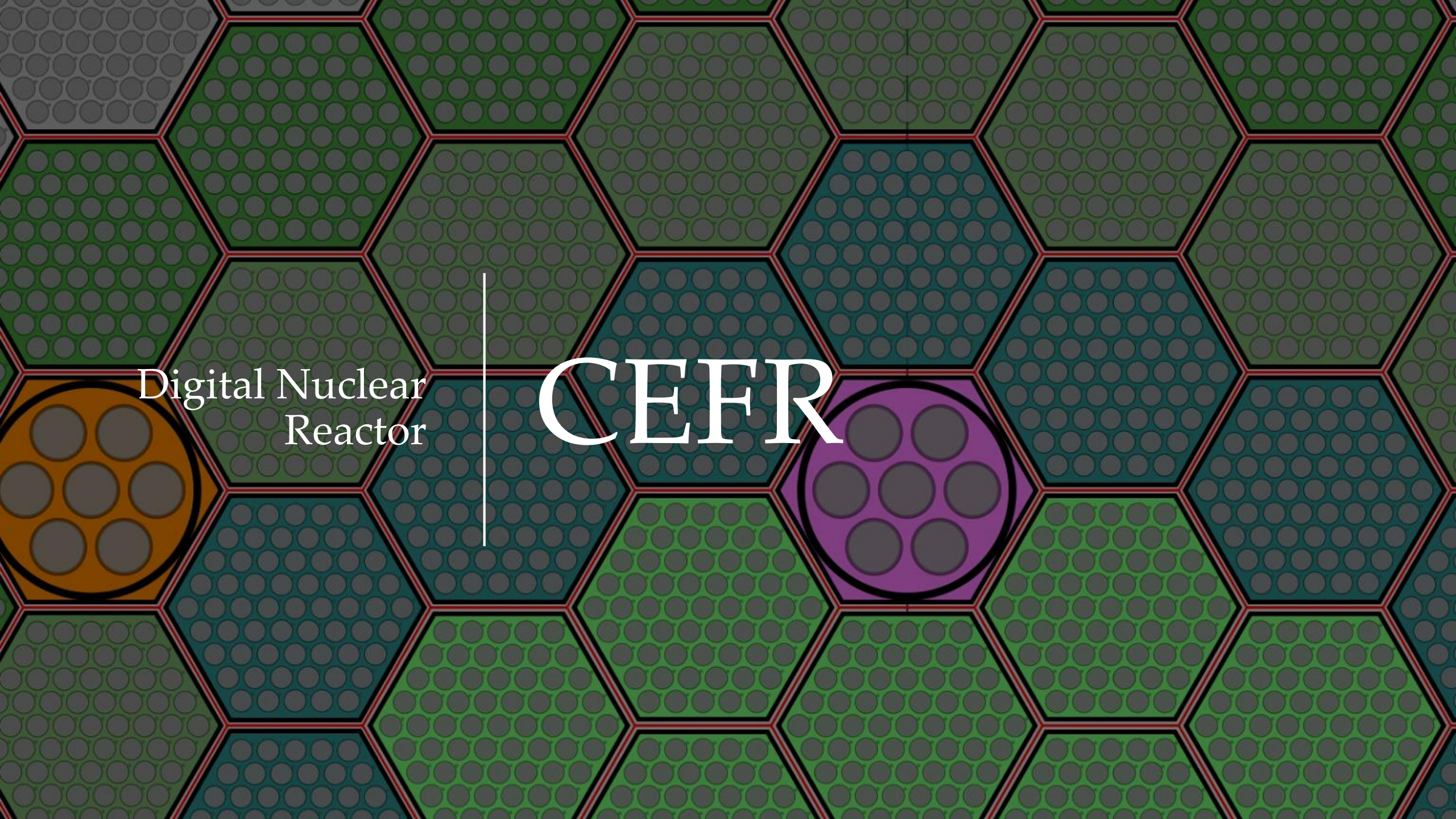
✓Distribute data to interested MSs for their use

- **Post CRP:**

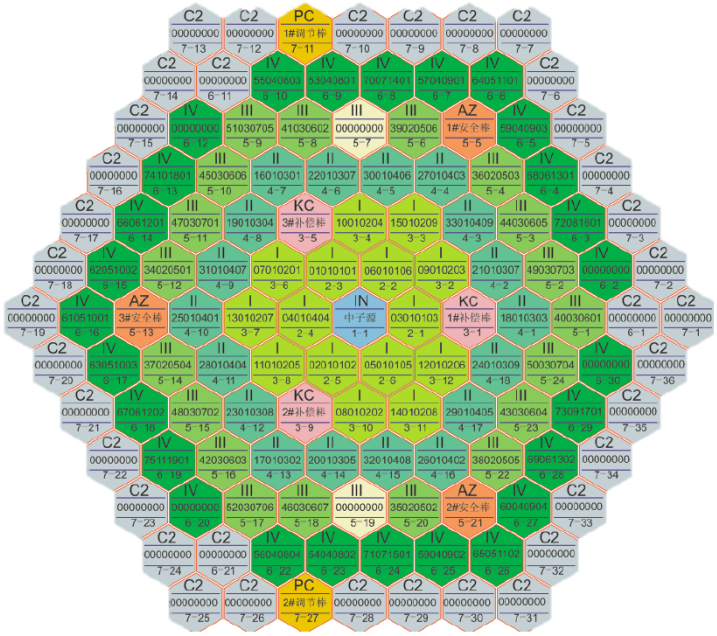
❖Preserve data and distribute as requested by new interested MSs






Digital Nuclear
Reactor
CEFR

Data from Technical Specifications



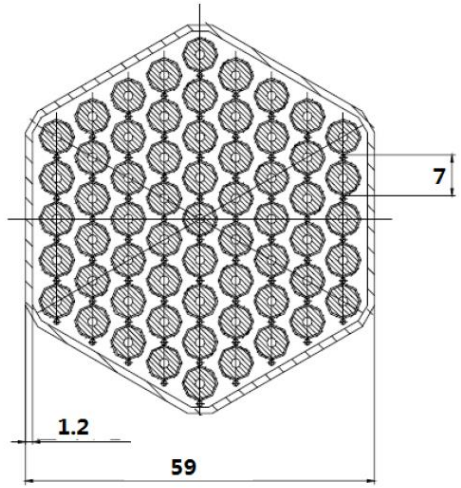


Figure 1 Cross sectional view of CEFR fuel SA

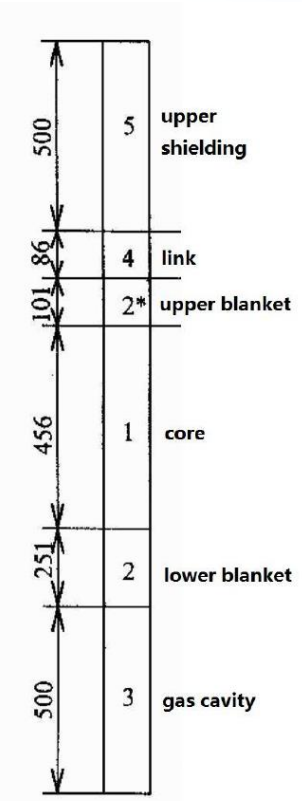
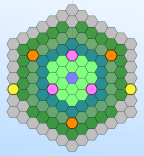


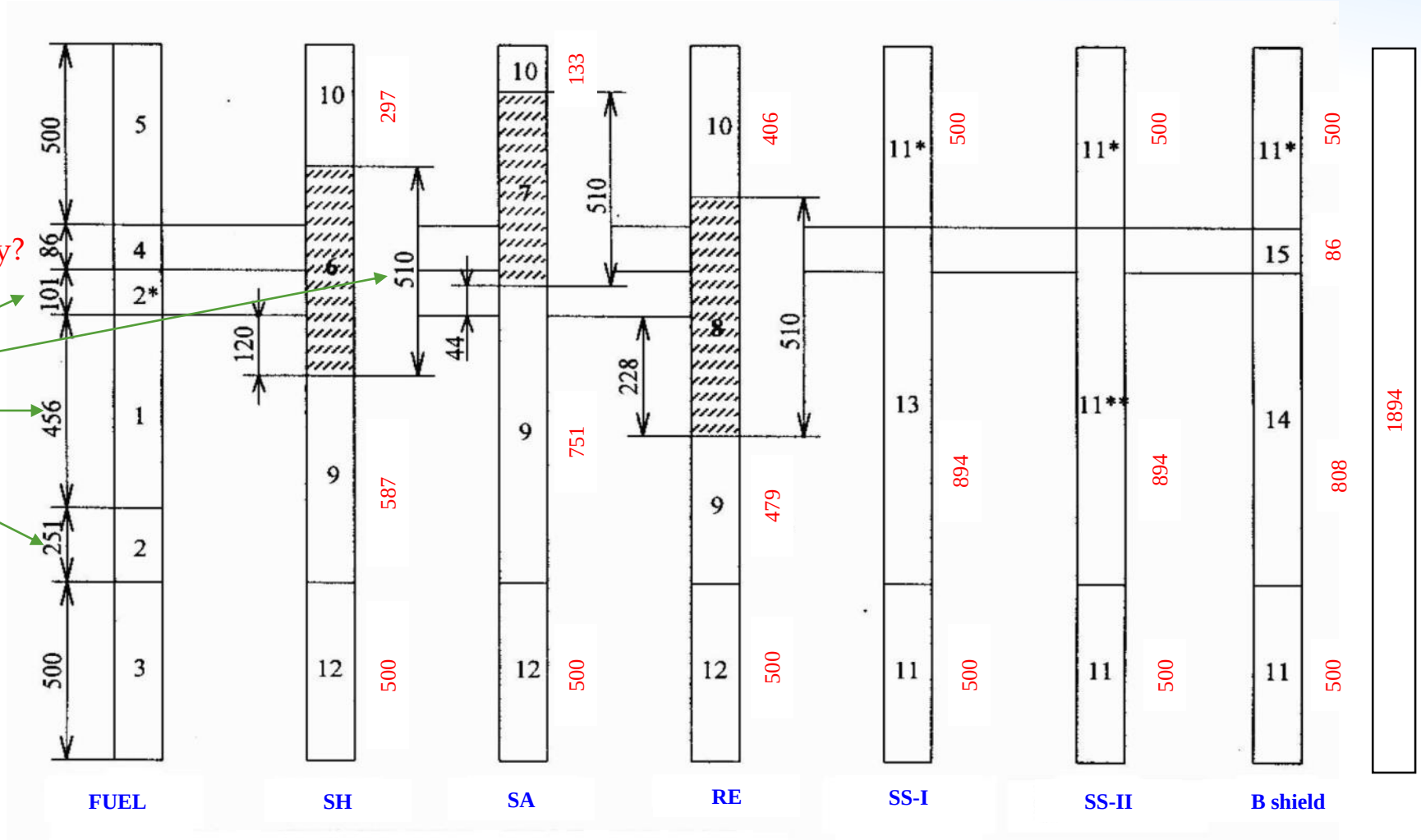
Figure 2 Axial structure of CEFR fuel SA

S/A Name	Type
KC	Shim Rod
AZ	Safety Rod
PC	Regulatory Rod
C2	Stainless Steel
IN	Neutron Source
I, II, III, IV	Fuel Rod

S/A Name	Type
SH (KC)	Shim Rod
SA (AZ)	Safety Rod
RE (PC)	Regulatory Rod
Fuel (I – IV)	Fuel Rod
SS-I (C2)	Stainless Steel
SS-II	Stainless Steel
B Shield	B4C Shielding



Subassemblies – Tech Spec



= 62 from geometry?

Expanded?

Not expanded?
= 488 in geometry

= why 1894? Which parts are not included?

Available
Calculated

Data Input

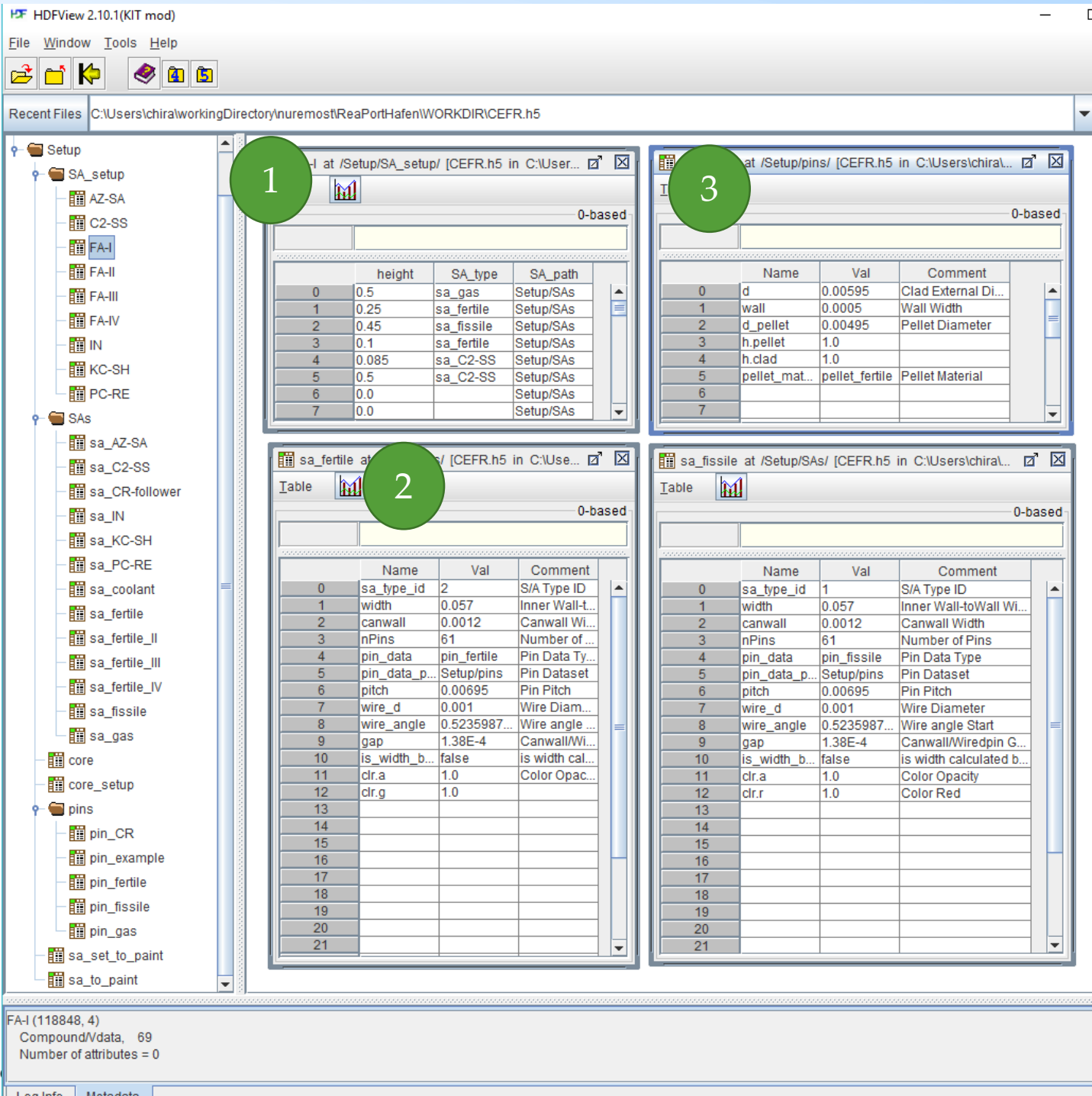
- **Step 1:**

Use subassembly geometry data and create HDF5 files with a simple interface to input data

i. Define axial distribution

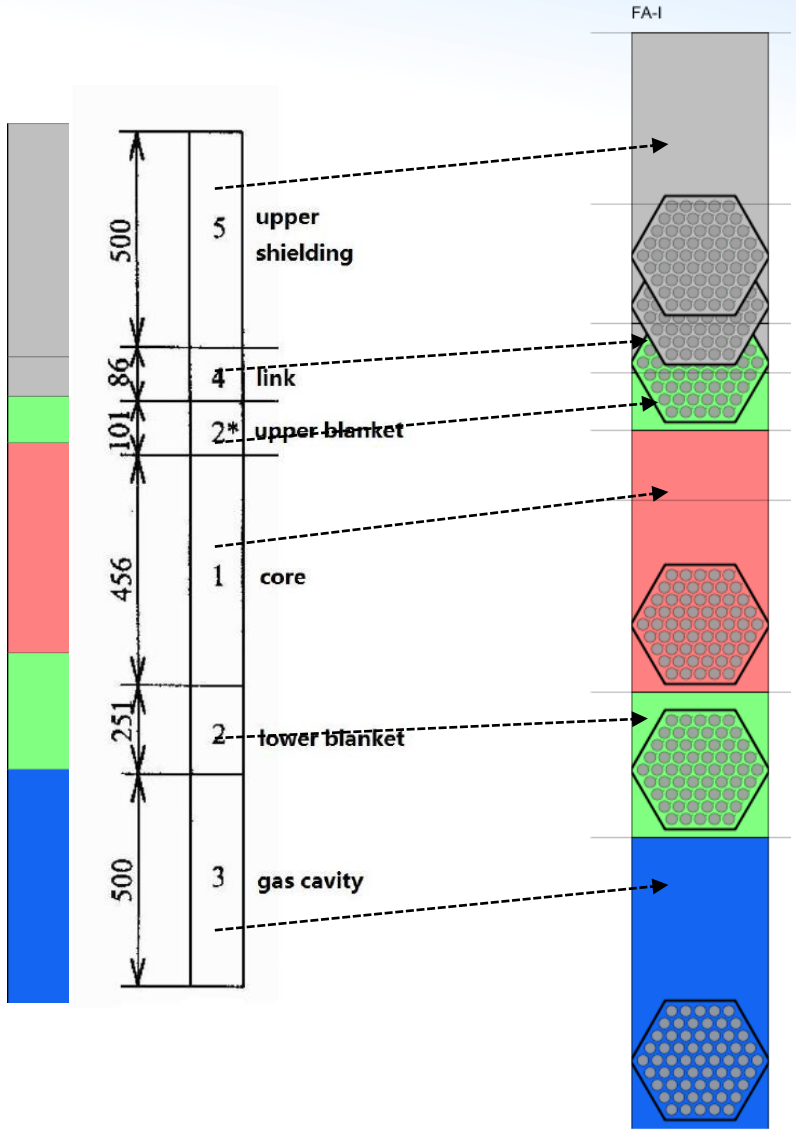
ii. Define each segment

iii. Define pin geometry and material

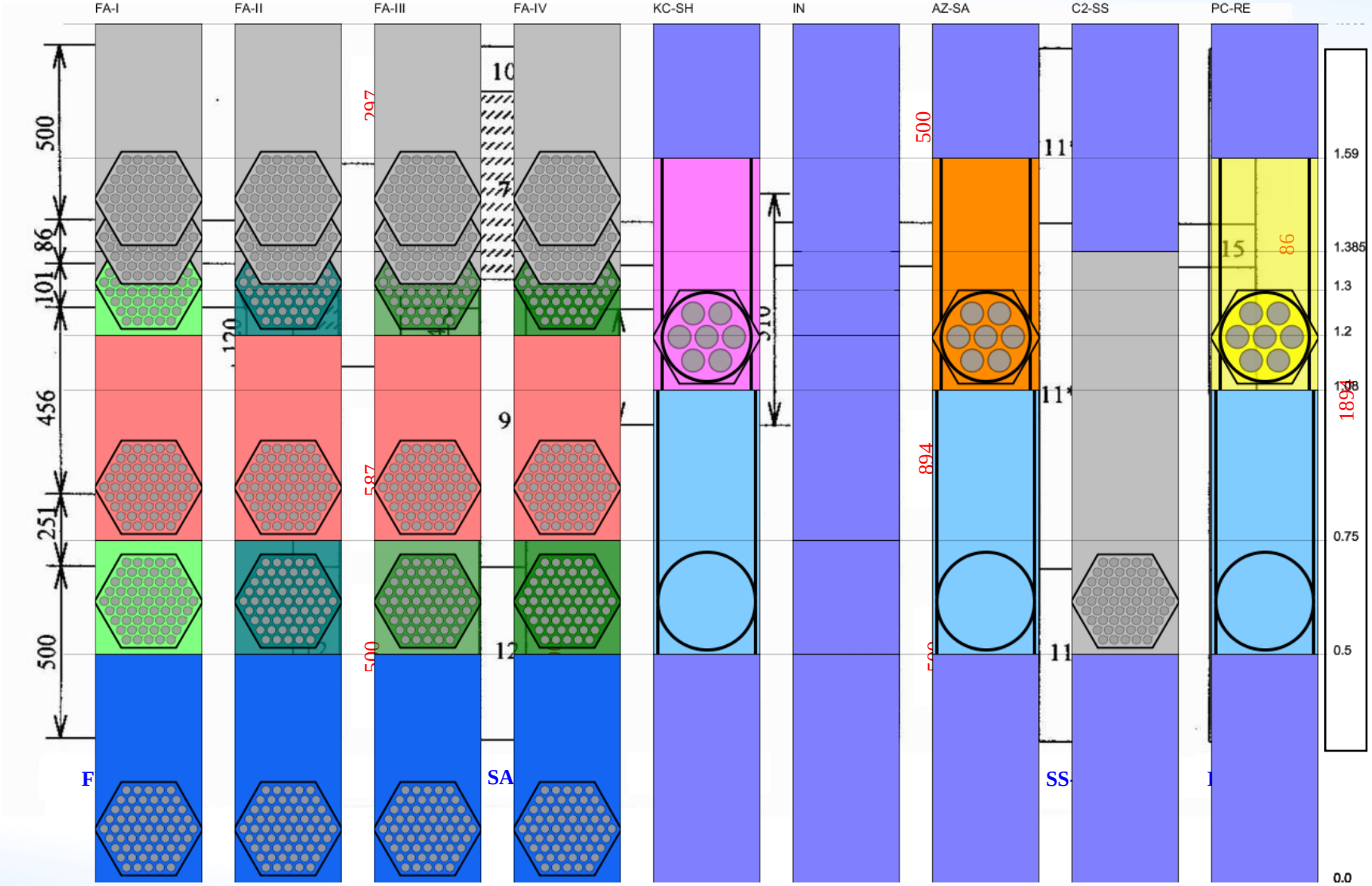


Eg.: Fuel Subassembly

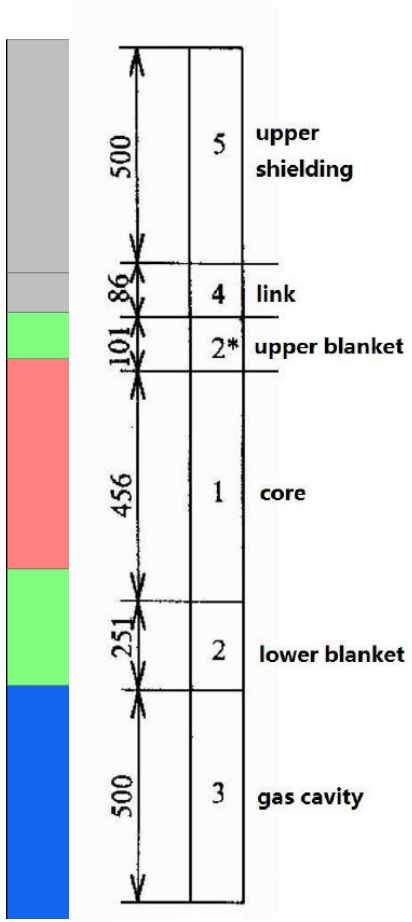
- Each axial segment defined via setup file
- Fuel pin structure and material also defined via setup file
- Currently hexagonal, cylindrical or rectangular geometry could be defined via available templates
- The isotopic composition could also be defined

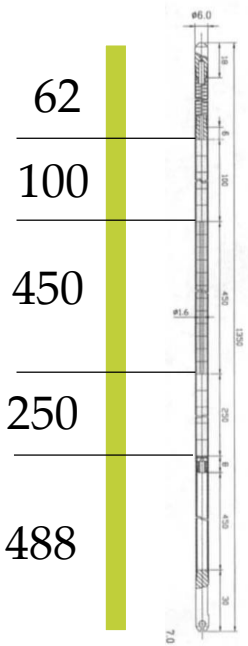


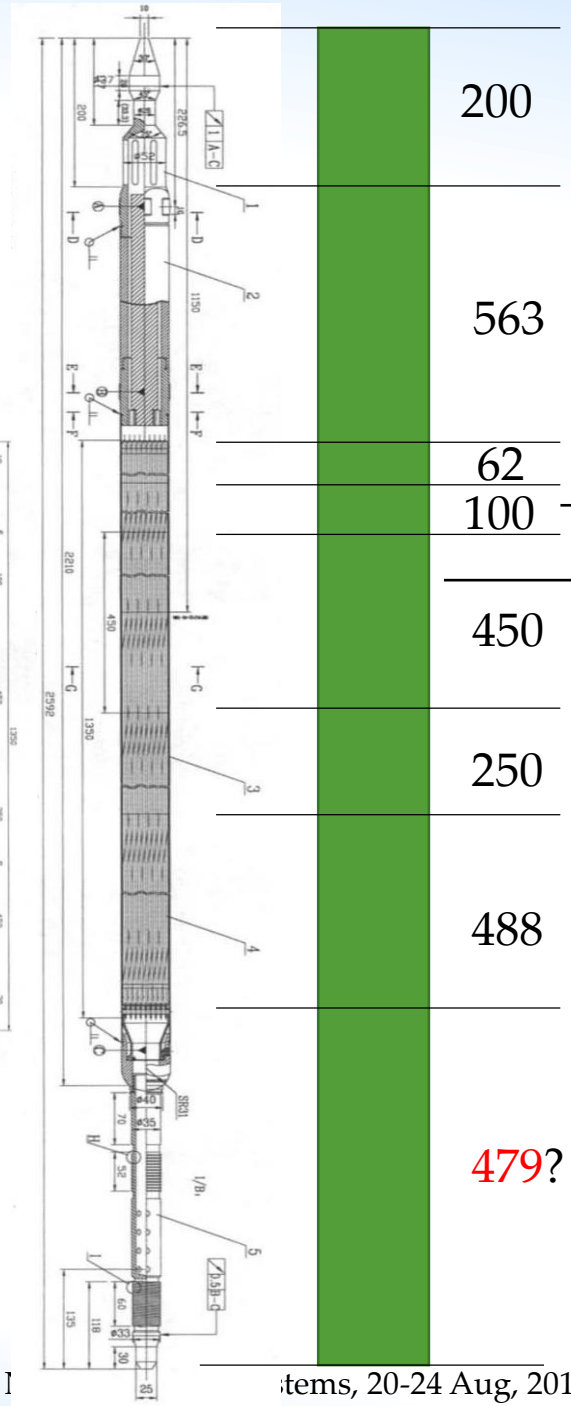
Subassemblies – Digital Reactor



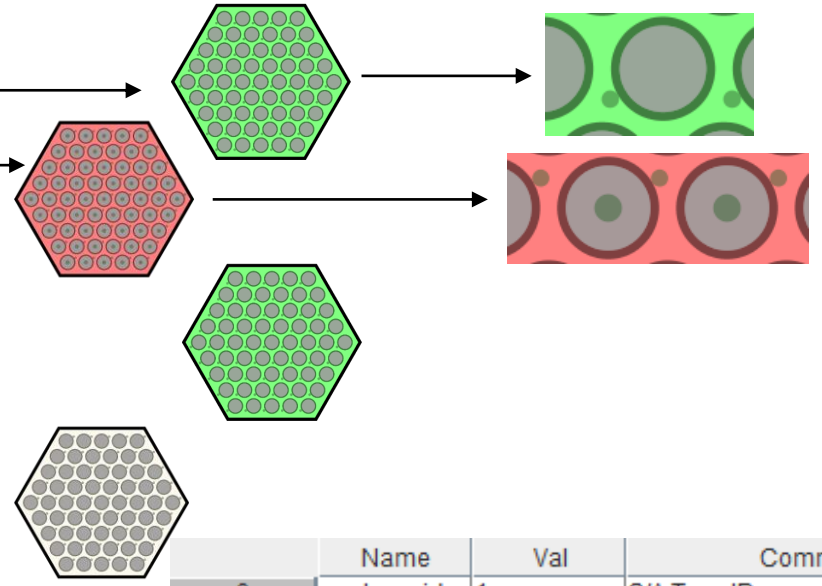
Fuel Subassembly







Fuel Subassembly	
Number of rods	61
Lattice pitch, mm	7
Outer flat-to-flat dimension, mm	59
Wrapper thickness, mm	1.2
Outer diameter of rod, mm	6
Thickness of cladding, mm	0.3
Diameter of pellet, mm	5.2
Diameter of spacer wire, mm	0.95

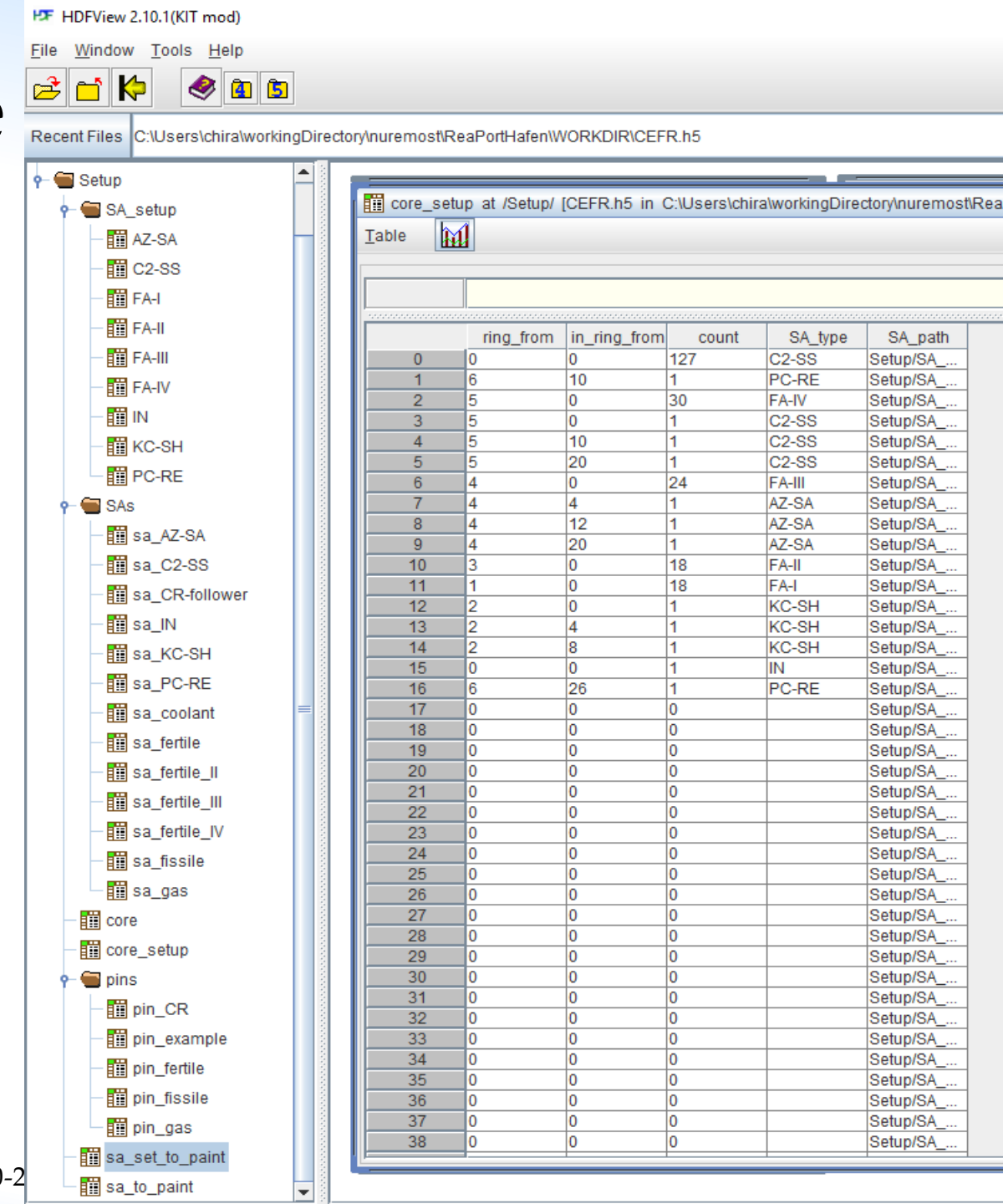


	Name	Val	Comment
0	sa_type_id	1	S/A Type ID
1	width	0.0566	Inner Wall-toWall Width
2	canwall	0.0012	Canwall Width
3	nPins	61	Number of Pins
4	pin_data	pin_fissile	Pin Data Type
5	pin_data_p...	Setup/pins	Pin Dataset
6	pitch	0.00695	Pin Pitch
7	wire_d	0.001	Wire Diameter
8	wire_angle	0.5235987...	Wire angle Start
9	gap	1.38E-4	Canwall/Wiredpin Gap
10	is_width_b...	false	is width calculated by gap size
11	clr.a	1.0	Color Opacity
12	clr.r	1.0	Color Red

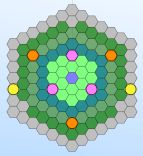
Place all assemblies in the core

- **Step 2:**

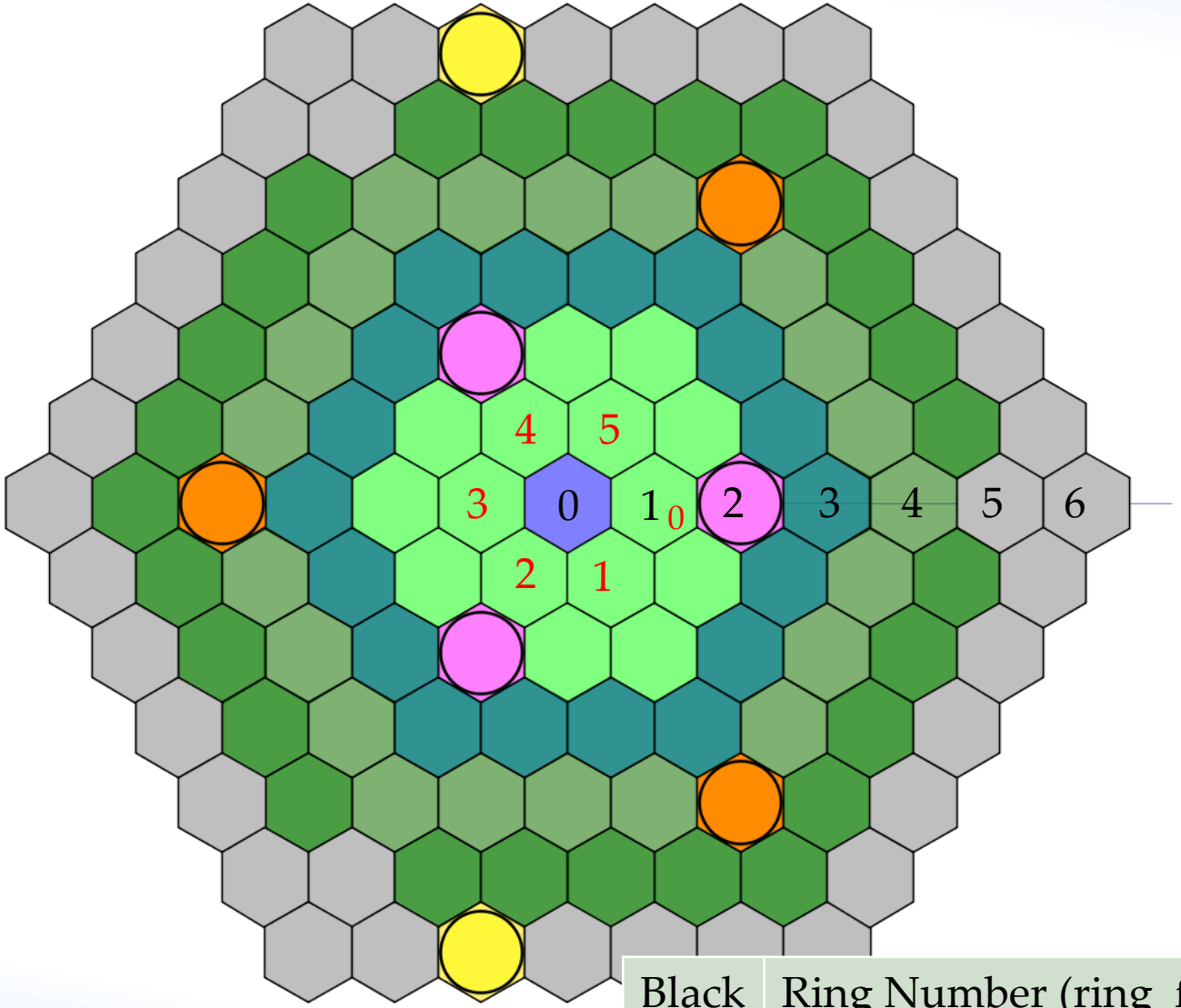
Arrange all assemblies in the reactor core to create the layout



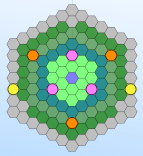
	ring_from	in_ring_from	count	SA_type	SA_path
0	0	0	127	C2-SS	Setup/SA_...
1	6	10	1	PC-RE	Setup/SA_...
2	5	0	30	FA-IV	Setup/SA_...
3	5	0	1	C2-SS	Setup/SA_...
4	5	10	1	C2-SS	Setup/SA_...
5	5	20	1	C2-SS	Setup/SA_...
6	4	0	24	FA-III	Setup/SA_...
7	4	4	1	AZ-SA	Setup/SA_...
8	4	12	1	AZ-SA	Setup/SA_...
9	4	20	1	AZ-SA	Setup/SA_...
10	3	0	18	FA-II	Setup/SA_...
11	1	0	18	FA-I	Setup/SA_...
12	2	0	1	KC-SH	Setup/SA_...
13	2	4	1	KC-SH	Setup/SA_...
14	2	8	1	KC-SH	Setup/SA_...
15	0	0	1	IN	Setup/SA_...
16	6	26	1	PC-RE	Setup/SA_...
17	0	0	0		Setup/SA_...
18	0	0	0		Setup/SA_...
19	0	0	0		Setup/SA_...
20	0	0	0		Setup/SA_...
21	0	0	0		Setup/SA_...
22	0	0	0		Setup/SA_...
23	0	0	0		Setup/SA_...
24	0	0	0		Setup/SA_...
25	0	0	0		Setup/SA_...
26	0	0	0		Setup/SA_...
27	0	0	0		Setup/SA_...
28	0	0	0		Setup/SA_...
29	0	0	0		Setup/SA_...
30	0	0	0		Setup/SA_...
31	0	0	0		Setup/SA_...
32	0	0	0		Setup/SA_...
33	0	0	0		Setup/SA_...
34	0	0	0		Setup/SA_...
35	0	0	0		Setup/SA_...
36	0	0	0		Setup/SA_...
37	0	0	0		Setup/SA_...
38	0	0	0		Setup/SA_...



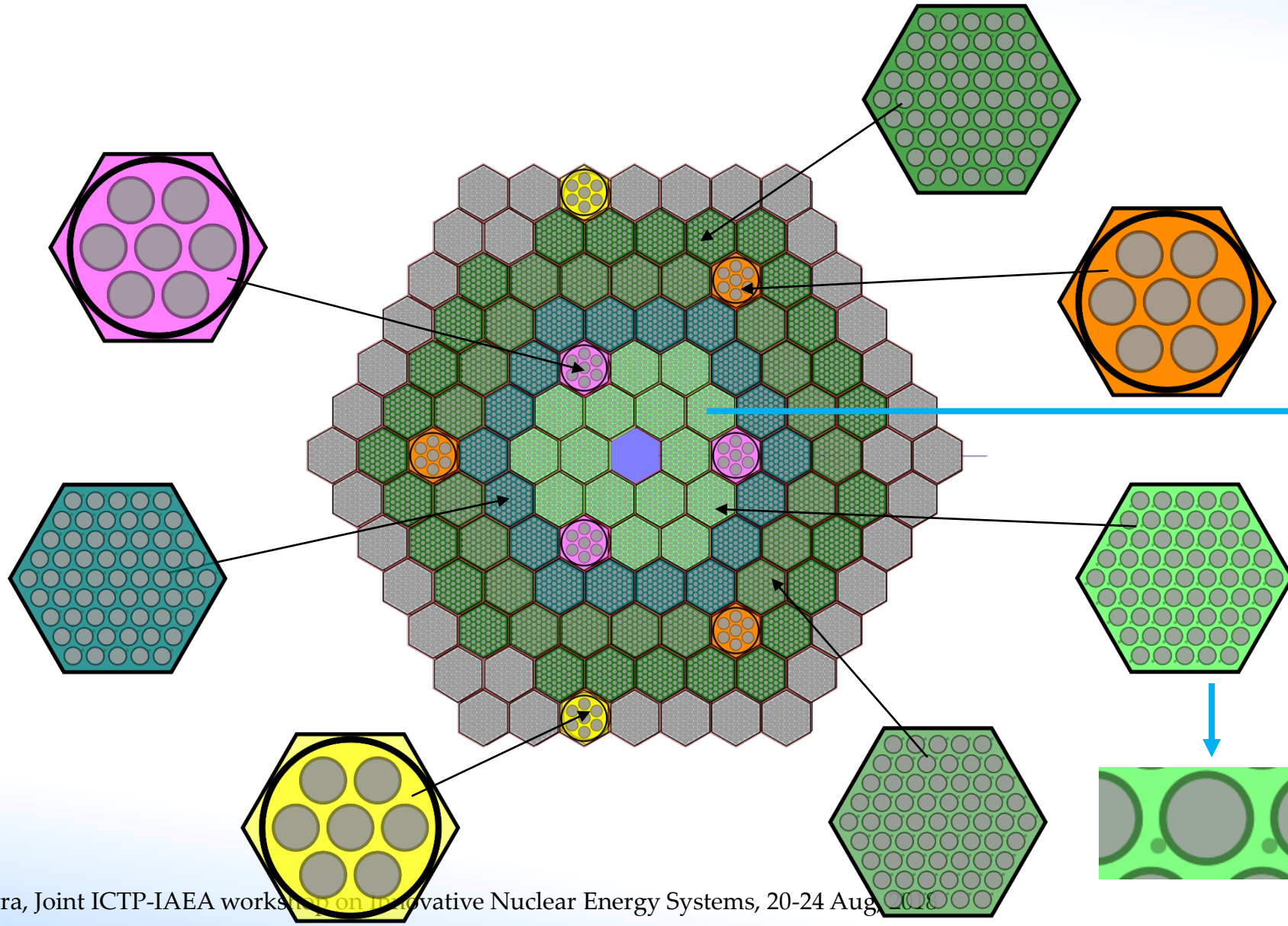
Core Map

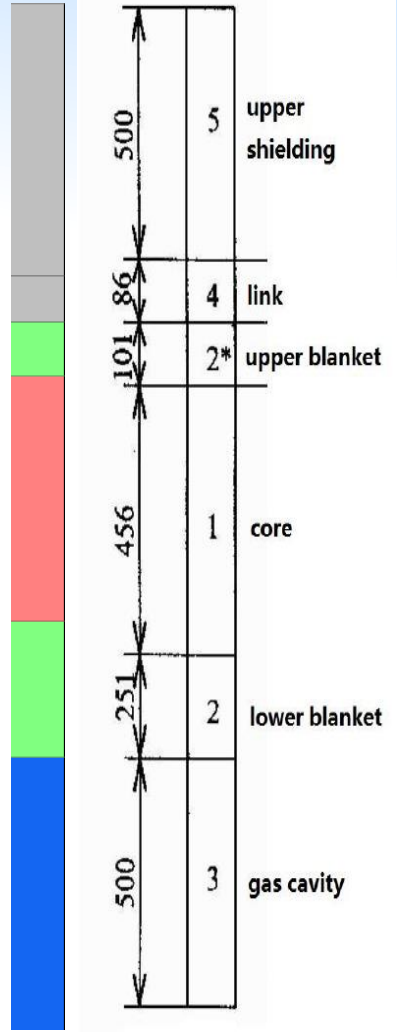


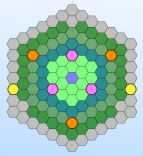
Black	Ring Number (ring_from)
Red	Number within ring (in_ring_from)



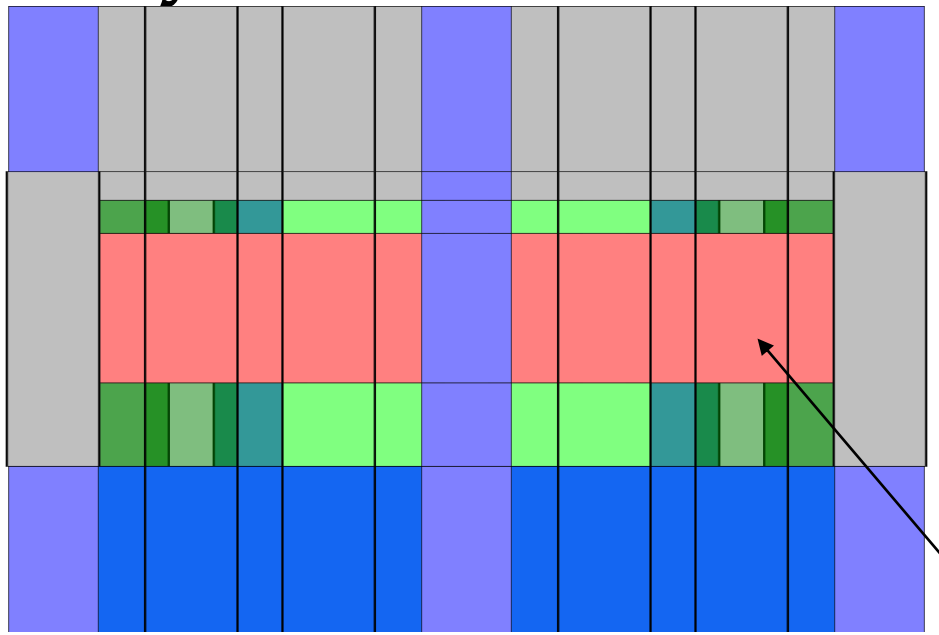
Complete Core Map



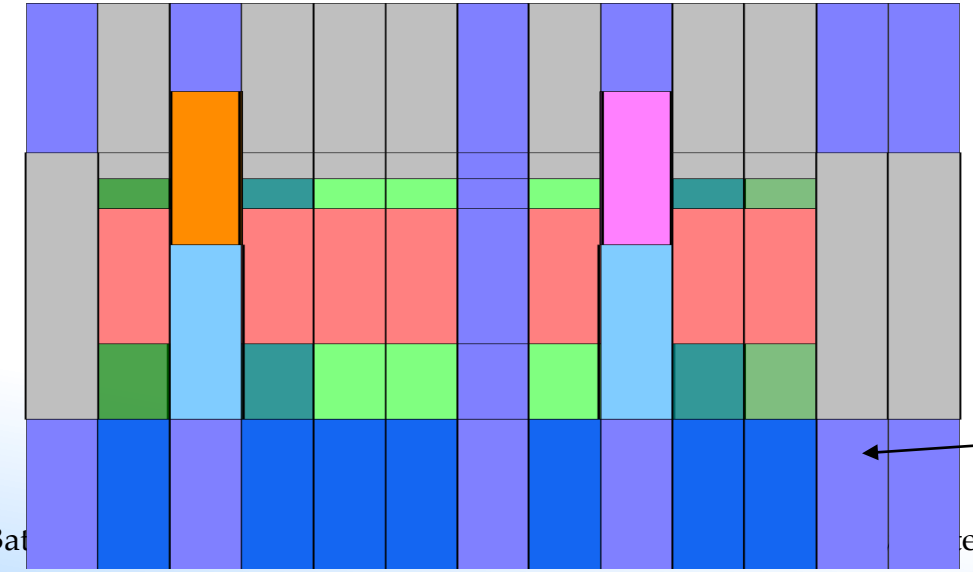




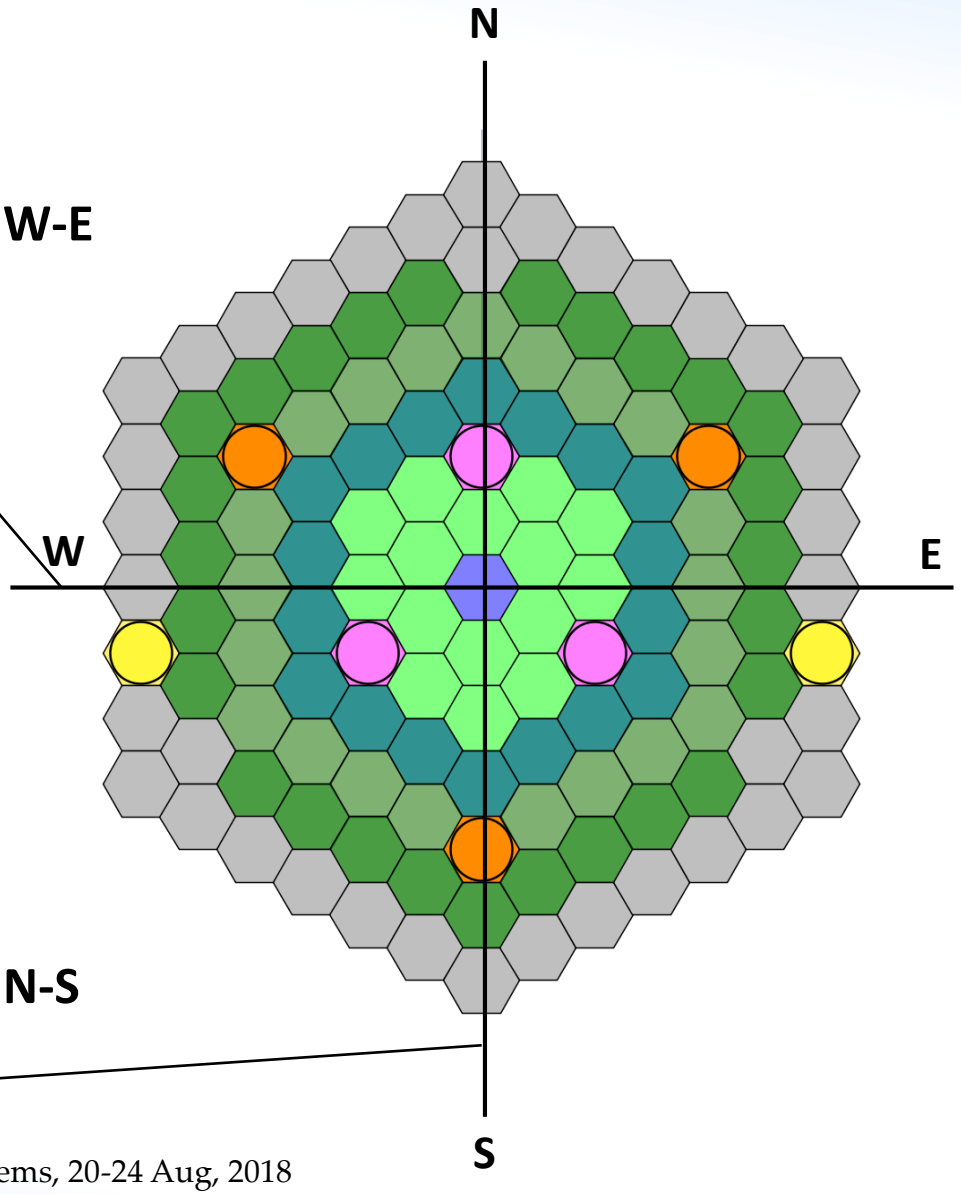
Core Layout

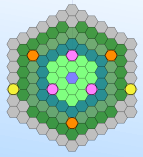


W-E

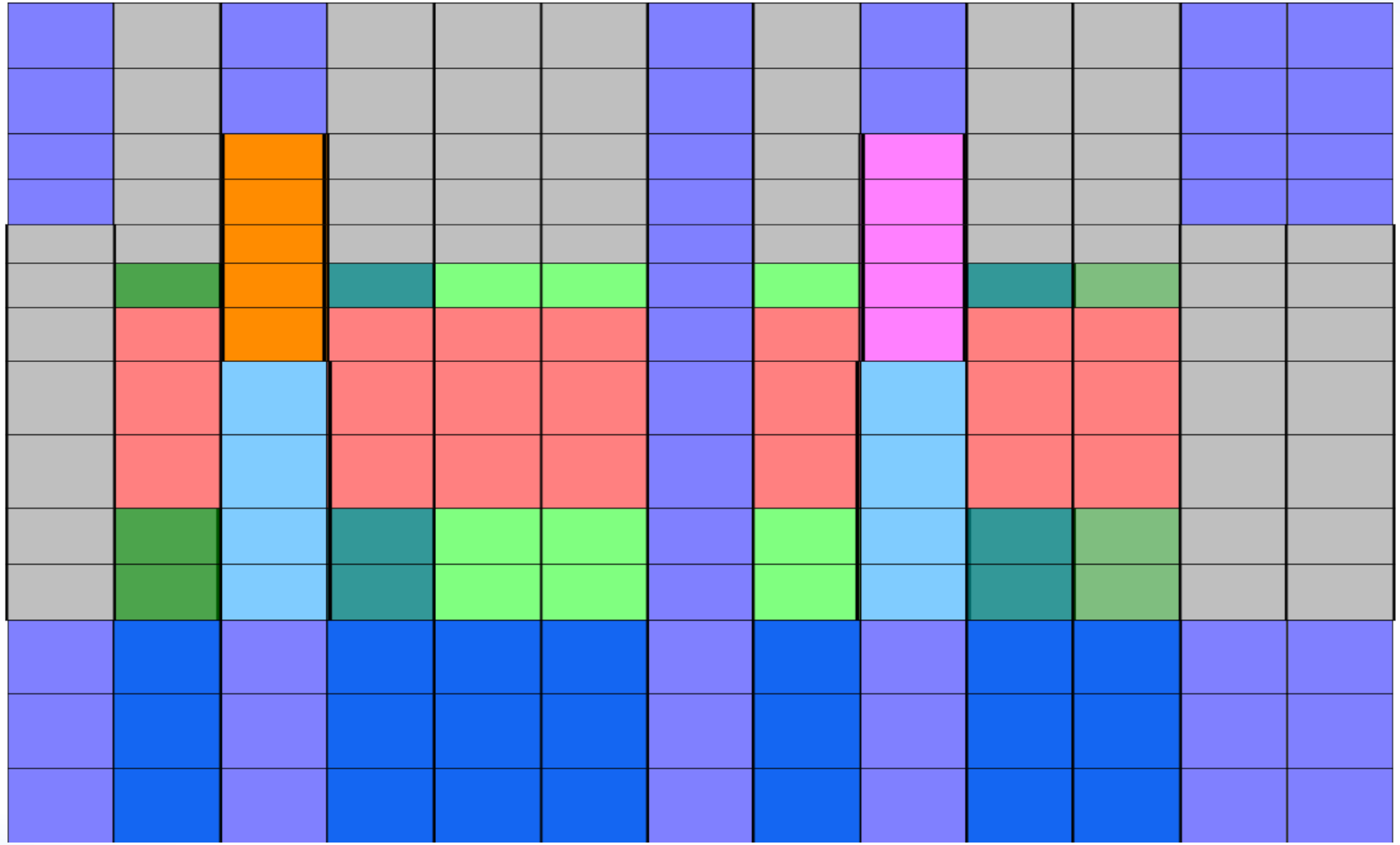


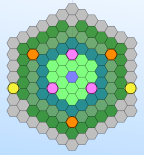
N-S



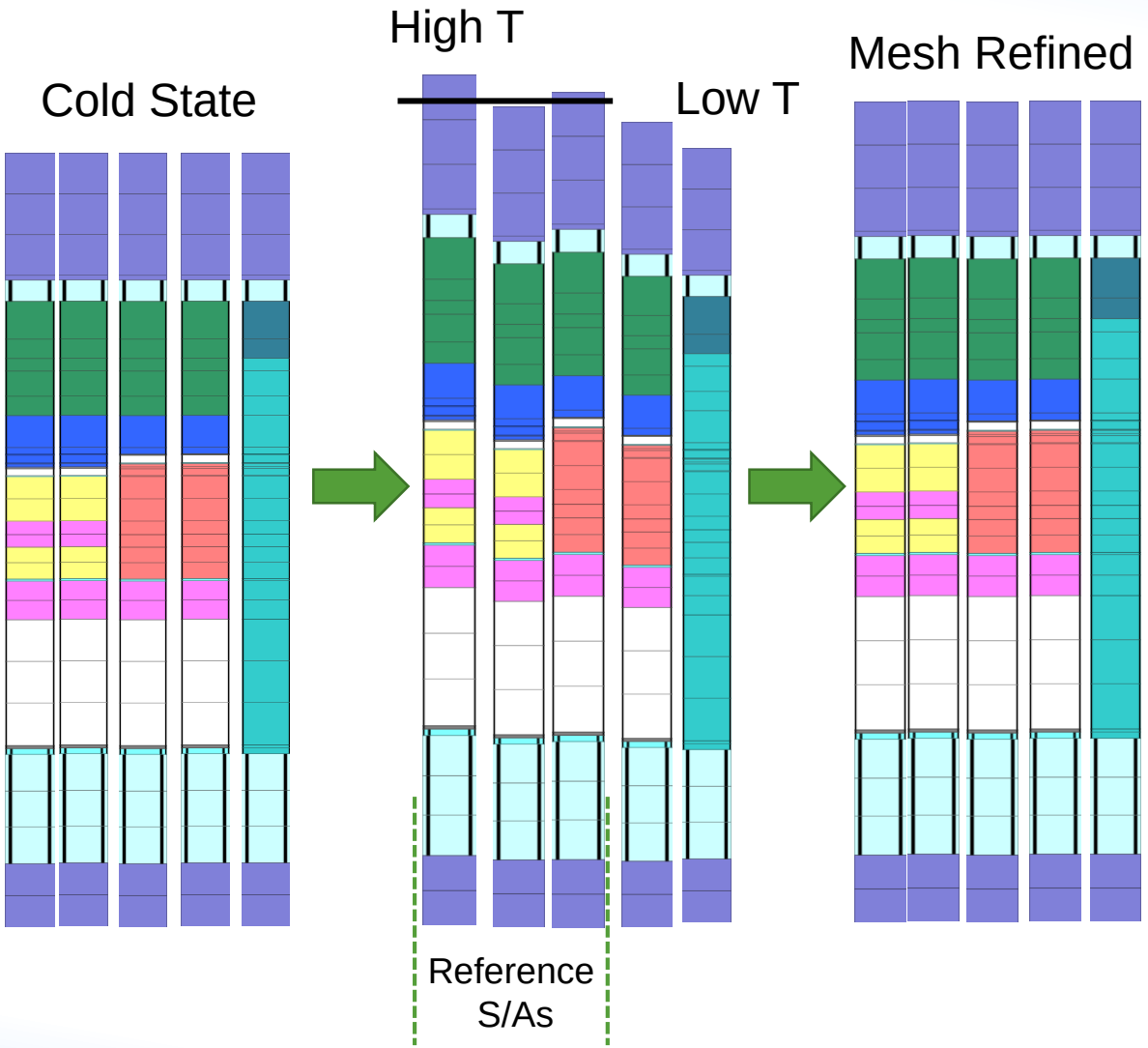


Additional Features: Meshing





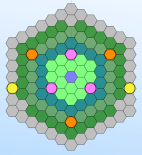
Additional Features: Thermal Expansion



Important!
Mass Conservation

Summary

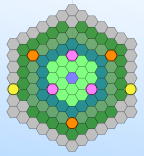
1. "**Digital Nuclear Reactor**" is an easy to use data storage toolkit that can be used to input all necessary reactor data for benchmark exercises
2. The CRP participants are free to use the data and can be provided to them
3. The interfaces to connect different codes can be developed
4. The tool can be used to assess if enough data is available to carry out the CRP, thus assuring availability of data before the kick-off meeting
5. Will reduce the risk of incorrect data input by the participants
6. Will lead to long term preservation of benchmark data and later the results (after post processing module is developed)
7. The data can then be distributed to interested member states after the CRP is completed along with the TECDOC
8. The toolkit can be used for educational purposes – simple calculations/simulations



Future Work

- Develop interfaces to couple different codes
  - Will try to make interface for SERPENT
- Perform simple calculations for thermal expansion
  - Based on the thermal expansion coefficients provided
- Develop other modules to do post-processing
- Make necessary changes in the graphical interface for better user experience
- Perform similar exercise for FFTF ULOF CRP

Acknowledgement: Thanks to KIT for the advice in the development of this toolkit



Thank you!

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