NURESAFE WP1.3
BWR ATWS WITH UNCERTAINTY QUANTIFICATION

DYN3D Input Deck for O2

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Outline

- ***D13.23 - Full core DNY3D input model of the Oskarshamn-2 NNP for ATWS analysis.***
  - Material maps definition
  - CR bank modeling

- **D13.23 delivered (May 2014), verification done.**

- **Preliminary results.**

- **Conclusion & Outlook**

XS library specifications

- **The CASMO code was applied to generate the 2-group macroscopic cross-sections needed for DYN3D calculations.**

- **The burnup and the historical parameters are implicitly included in the macroscopic cross-section. 25 axial nodes in the active core are used.**

- **Fifteen branching points for the moderator density are selected. They range from the core inlet density up to the minimum core exit density (in kg/m^3):**

    176.68, 177.44, 177.53, 317.95, 330.85,

    341.59, 458.37, 485.01, 505.74, 598.79,

    639.18, 669.89, 739.20, 793.35, 834.04.

- **Eight fuel temperature branching points are selected (in K):**

    500, 650, 800, 950,1100, 1250, 1400, and 1550.

XS library specifications

- **The half core rotational symmetry is used to limit the number of materials therefore leading to a total of different fuel materials of 444/2 * 25 (rodded) + 444/2 *25 (unrodded) + 3 reflector = 11103 XS sets.**

- **The XS library is given in 2G NEMTAB format:**
  - Diffusion coefficient
  - Absorption cross-section
  - Fission cross-section
  - Nu-fission cross-section
  - Scattering cross-section (only from group 1 to group 2)
  - ADF-West
  - ADF-South
  - Macroscopic Xe cross-section (only for group 2)
  - Microscopic Xe cross-section (only for group 2)

O2 Core loading according to the XS library

- **In the XS library, 11103 different materials compositions are defined which correspond to 445 (222+1+222) sets of fuel assemblies, they are classified as follow:**
  - Fuel Assemblies from 1 to 222 → rodded, material from 5554 to 11103
  - Fuel Assembly 223→ radial reflector, materials 5551, 5552 and 5553
  - Fuel Assemblies from 224 to 445 → unrodded, materials from 1 to 5550

Composition # Axial Layer rodded   **Composition # Axial Layer Unrodded**

	1	2	3	4	5	...	222	223
1	5551	5551	5551	5551	5551	...	5551	5551
2	1	26	51	76	101	...	5526	5552
3	2	27	52	77	102	...	5527	5552
4	3	28	53	78	103	...	5528	5552
5	4	29	54	79	104	...	5529	5552
6	5	30	55	80	105	...	5530	5552
7	6	31	56	81	106	...	5531	5552
8	7	32	57	82	107	...	5532	5552
9	8	33	58	83	108	...	5533	5552
10	9	34	59	84	109	...	5534	5552
11	10	35	60	85	110	...	5535	5552
12	11	36	61	86	111	...	5536	5552
13	12	37	62	87	112	...	5537	5552
14	13	38	63	88	113	...	5538	5552
15	14	39	64	89	114	...	5539	5552
16	15	40	65	90	115	...	5540	5552
17	16	41	66	91	116	...	5541	5552
18	17	42	67	92	117	...	5542	5552
19	18	43	68	93	118	...	5543	5552
20	19	44	69	94	119	...	5544	5552
21	20	45	70	95	120	...	5545	5552
22	21	46	71	96	121	...	5546	5552
23	22	47	72	97	122	...	5547	5552
24	23	48	73	98	123	...	5548	5552
25	24	49	74	99	124	...	5549	5552
26	25	50	75	100	125	...	5550	5552
27	5553	5553	5553	5553	5553	...	5553	5553

Bottom Reflector

11,96
31,33
46,18
61,03
75,88
90,73
105,57
120,42
135,27
150,12
164,97
179,81
194,66
209,51
224,36
239,21
254,05
268,9
283,75
298,6
313,45
328,29
343,14
357,99
372,84
387,69
414,19

Top Reflector

	1	2	3	4	5	...	222	223
1	5551	5551	5551	5551	5551	...	5551	5551
2	5554	5579	5604	5629	5654	...	11079	5552
3	5555	5580	5605	5630	5655	...	11080	5552
4	5556	5581	5606	5631	5656	...	11081	5552
5	5557	5582	5607	5632	5657	...	11082	5552
6	5558	5583	5608	5633	5658	...	11083	5552
7	5559	5584	5609	5634	5659	...	11084	5552
8	5560	5585	5610	5635	5660	...	11085	5552
9	5561	5586	5611	5636	5661	...	11086	5552
10	5562	5587	5612	5637	5662	...	11087	5552
11	5563	5588	5613	5638	5663	...	11088	5552
12	5564	5589	5614	5639	5664	...	11089	5552
13	5565	5590	5615	5640	5665	...	11090	5552
14	5566	5591	5616	5641	5666	...	11091	5552
15	5567	5592	5617	5642	5667	...	11092	5552
16	5568	5593	5618	5643	5668	...	11093	5552
17	5569	5594	5619	5644	5669	...	11094	5552
18	5570	5595	5620	5645	5670	...	11095	5552
19	5571	5596	5621	5646	5671	...	11096	5552
20	5572	5597	5622	5647	5672	...	11097	5552
21	5573	5598	5623	5648	5673	...	11098	5552
22	5574	5599	5624	5649	5674	...	11099	5552
23	5575	5600	5625	5650	5675	...	11100	5552
24	5576	5601	5626	5651	5676	...	11101	5552
25	5577	5602	5627	5652	5677	...	11102	5552
26	5578	5603	5628	5653	5678	...	11103	5552
27	5553	5553	5553	5553	5553	...	5553	5553

Geometry definition

- **The radial node width is assumed to be 15.275 cm.**

- **The active core height is 371.2 cm and is uniformly divided into 25 segments of 14.848 cm each.**

- **As far as the homogenization is concerned:**

  - The active core starts from node 2 end ends in node 26

  - Node 1 is the bottom reflector

  - Node 27 is the top reflector

- **Bottom reflector has 23.91 cm and a top reflector 38.15 cm (in ATHLET is the same).**

CR Bank definition

- **In the Oskarshamn-2 power plant the control rods are grouped in 19 banks.**

	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
-12					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
-11			0	0	13	13	14	14	17	17	10	10	11	11	14	14	15	15	0	0				
-10		0	0	0	13	13	14	14	17	17	10	10	11	11	14	14	15	15	0	0	0			
-9		0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	9	9	0	0	
-8	0	0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	9	9	0	0	0
-7	0	11	11	12	12	15	15	16	16	9	9	12	12	13	13	16	16	17	17	12	12	11	11	0
-6	0	11	11	12	12	15	15	16	16	9	9	12	12	13	13	16	16	17	17	12	12	11	11	0
-5	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
-4	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
-3	0	9	9	14	14	13	13	10	10	17	17	14	14	11	11	19	19	15	15	14	14	13	13	0
-2	0	9	9	14	14	13	13	10	10	17	17	14	14	11	11	19	19	15	15	14	14	13	13	0
-1	0	4	4	1	1	2	2	7	7	8	8	18	18	6	6	3	3	4	4	1	1	2	2	0
0	0	4	4	1	1	2	2	7	7	8	8	18	18	6	6	3	3	4	4	1	1	2	2	0
1	0	15	15	16	16	11	11	19	19	15	15	16	16	9	9	12	12	17	17	16	16	11	11	0
2	0	15	15	16	16	11	11	19	19	15	15	16	16	9	9	12	12	17	17	16	16	11	11	0
3	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
4	0	8	8	5	5	6	6	3	3	4	4	1	1	2	2	7	7	8	8	5	5	6	6	0
5	0	9	9	10	10	17	17	14	14	13	13	10	10	11	11	14	14	13	13	10	10	9	9	0
6	0	9	9	10	10	17	17	14	14	13	13	10	10	11	11	14	14	13	13	10	10	9	9	0
7	0	0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	1	1	0	0	0
8		0	0	1	1	2	2	7	7	8	8	5	5	6	6	3	3	4	4	1	1	0	0	
9		0	0		15	15	16	16	9	9	12	12	17	17	16	16	15	15	0	0	0	0		
10		0	0		15	15	16	16	9	9	12	12	17	17	16	16	15	15	0	0				
11					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

- **The material composition of the fuel unrodded assemblies.**

	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
-12					223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				
-11				223	223	224	225	226	227	228	229	230	445	444	443	442	441	440	439	223	223			
-10			223	223	231	232	233	234	235	236	237	238	438	437	436	435	434	433	432	431	223	223		
-9		223	223	239	240	241	242	243	244	245	246	247	430	429	428	427	426	425	424	423	422	223	223	
-8	223	223	248	249	250	251	252	253	254	255	256	257	421	420	419	418	417	416	415	414	413	412	223	223
-7	223	258	259	260	261	262	263	264	265	266	267	268	411	410	409	408	407	406	405	404	403	402	401	223
-6	223	269	270	271	272	273	274	275	276	277	278	279	400	399	398	397	396	395	394	393	392	391	390	223
-5	223	280	281	282	283	284	285	286	287	288	289	290	389	388	387	386	385	384	383	382	381	380	379	223
-4	223	291	292	293	294	295	296	297	298	299	300	301	378	377	376	375	374	373	372	371	370	369	368	223
-3	223	302	303	304	305	306	307	308	309	310	311	312	367	366	365	364	363	362	361	360	359	358	357	223
-2	223	313	314	315	316	317	318	319	320	321	322	323	356	355	354	353	352	351	350	349	348	347	346	223
-1	223	324	325	326	327	328	329	330	331	332	333	334	345	344	343	342	341	340	339	338	337	336	335	223
0	223	335	336	337	338	339	340	341	342	343	344	345	334	333	332	331	330	329	328	327	326	325	324	223
1	223	346	347	348	349	350	351	352	353	354	355	356	323	322	321	320	319	318	317	316	315	314	313	223
2	223	357	358	359	360	361	362	363	364	365	366	367	312	311	310	309	308	307	306	305	304	303	302	223
3	223	368	369	370	371	372	373	374	375	376	377	378	301	300	299	298	297	296	295	294	293	292	291	223
4	223	379	380	381	382	383	384	385	386	387	388	389	290	289	288	287	286	285	284	283	282	281	280	223
5	223	390	391	392	393	394	395	396	397	398	399	400	279	278	277	276	275	274	273	272	271	270	269	223
6	223	401	402	403	404	405	406	407	408	409	410	411	268	267	266	265	264	263	262	261	260	259	258	223
7	223	223	412	413	414	415	416	417	418	419	420	421	257	256	255	254	253	252	251	250	249	248	223	223
8		223	223	422	423	424	425	426	427	428	429	430	248	246	245	244	243	242	241	240	239	223	223	
9			223	223	431	432	433	434	435	436	437	438	238	237	236	235	234	233	232	231	223	223		
10			223	223	439	440	441	442	443	444	445		230	229	228	227	226	225	224	223	223			
11					223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223				

- **For modeling CR entering from the bottom of the core with DYN3D.**

Insertion in the DYN3D input file is always defined from the top of the core.

Unrodded material

Rodded material

ARO => tip at z=0.0   ARI => tip at z=371.2

z=371.2

z=0.0

z=371.2

z=0.0
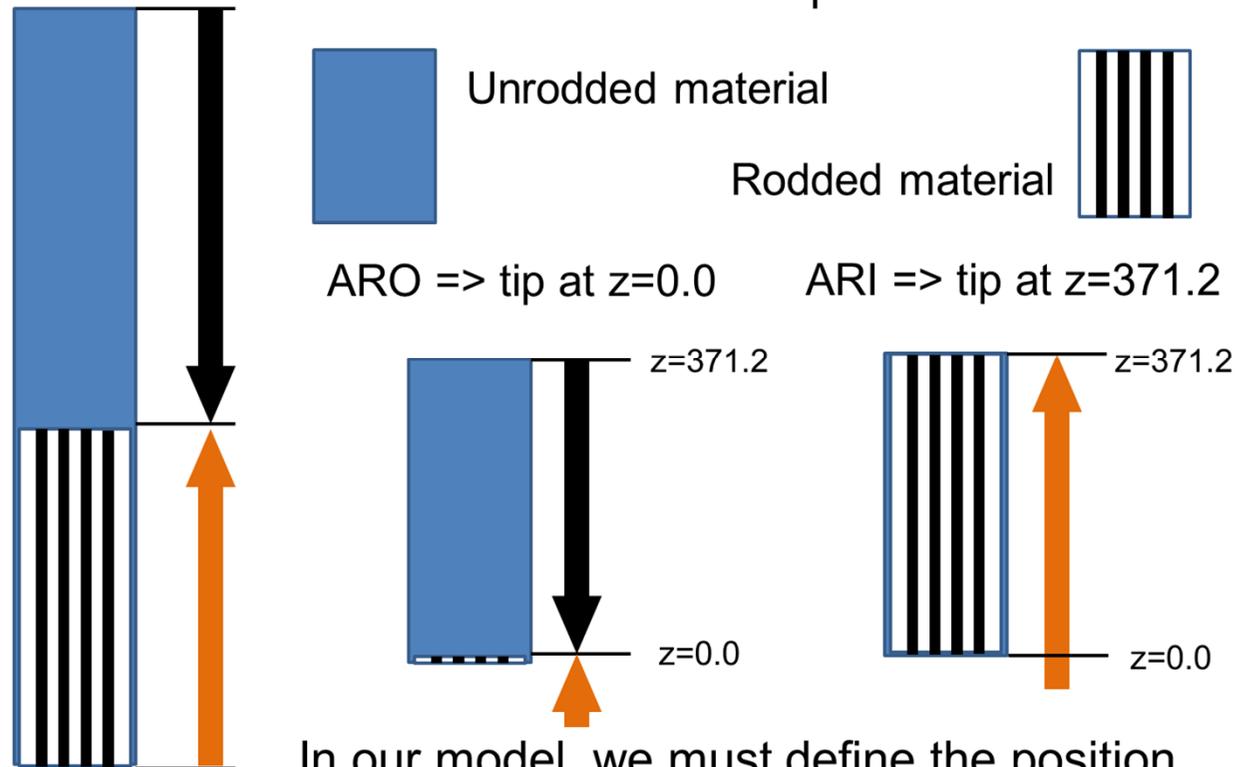
In our model, we must define the position from the bottom of the core.

Preliminary Steady State Results obtained with DYN3D

Considered cases

- **Objective: Checking the XS library by inserting the CR Banks at 5 different elevations, considering 5 different cases.**

- **DYN3D is coupled with FLOCAL.**

Case 1

- **Oskarshamn-2 input deck with XS library given by Benchmark organizers.**

Calc. Failed

Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.014586	NaN
71.2	1.14575	NaN
171.2	1.014196	NaN
271.2	1.004227	NaN
371.2 (ARI)	0.796669	NaN

- **Power is very much displaced to the top of the core.**

Elevation	Keff HZP
0.0 (ARO)	1.014586
71.2	1.14575
171.2	1.014196
271.2	1.004227
371.2 (ARI)	0.796669
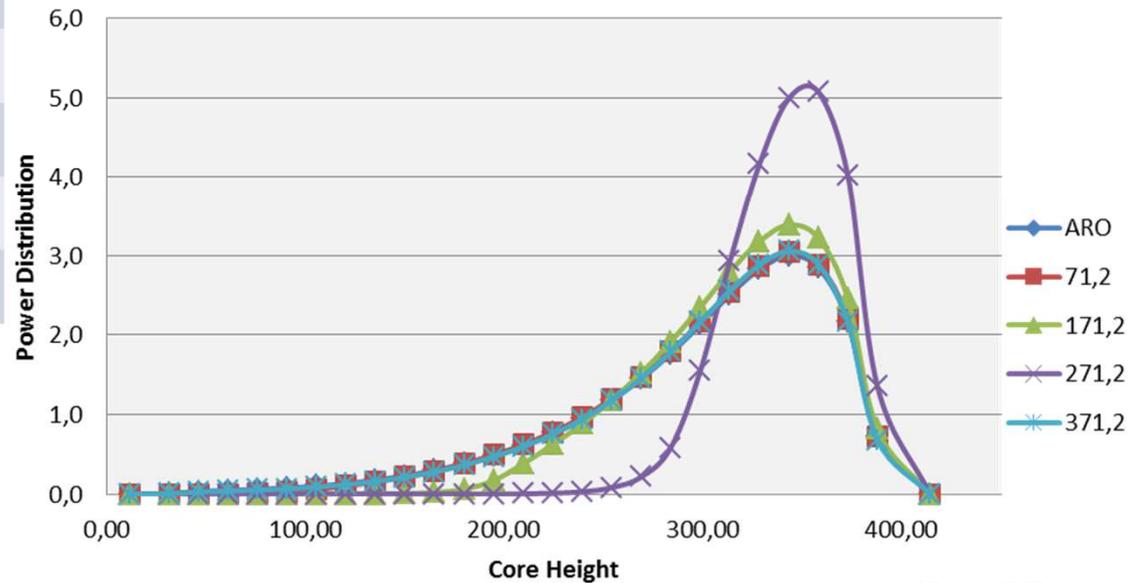
Oskarshamn-2
Average Axial Power Distribution HZP
Several Control Rod Positions

Bottom of the core

Top of the core

Case 2
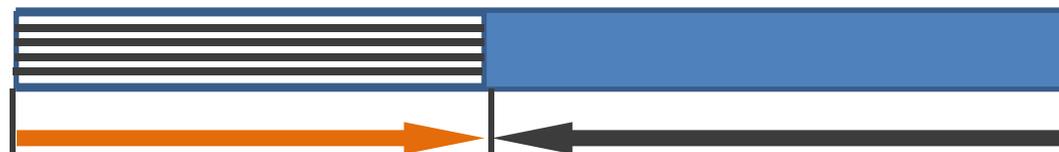
- **Oskarshamn-2 input deck with XS library given by Benchmark organizers, but inverting axially the materials in the FA (Slide 6).**

Elevation	Keff HZP
0.0 (ARO)	1.014099
71.2	0.997035
171.2	0.988555
271.2	0.969849
371.2 (ARI)	0.795158

HFP
Calc. Failed

Oskarshamn-2
Average Axial Power Distribution HZP
Several Control Rod Positions
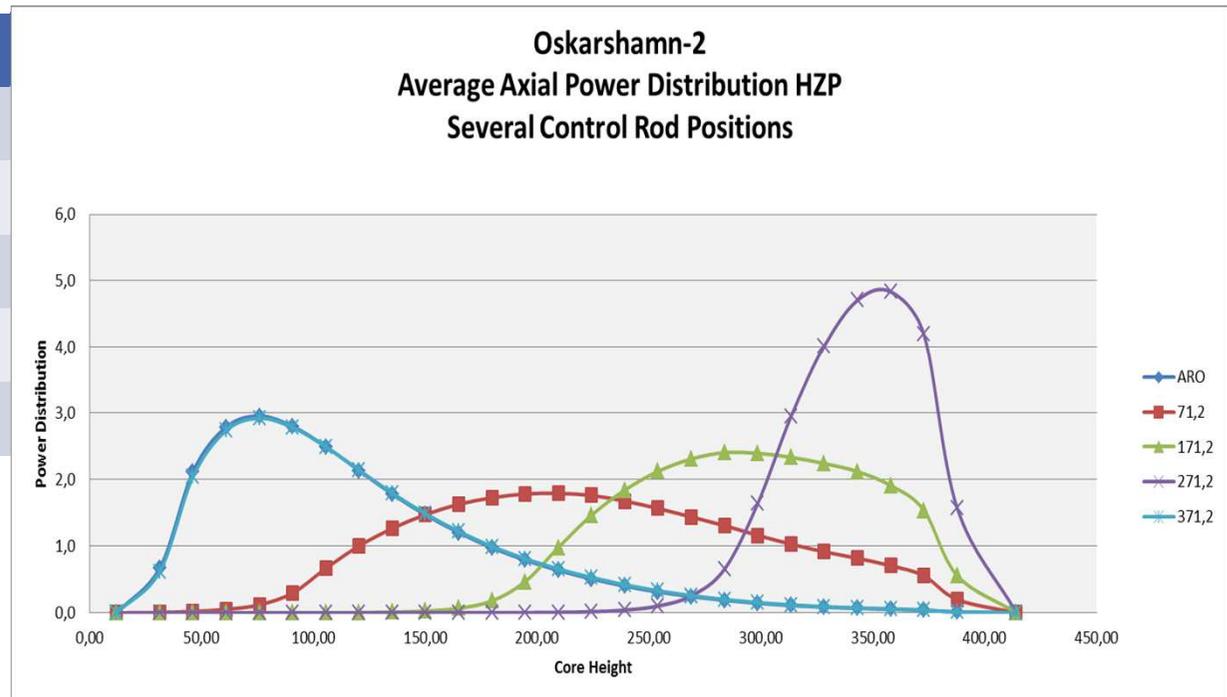
Bottom of the core

Top of the core
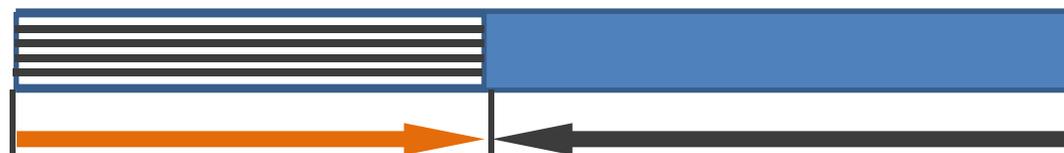
Case 3

- **Peach Bottom Benchmark (Previously validated XS libraries).**
- **DYN3D results coupled with FLOCAL.**
- **Analysis of the axial power profile.**
- **Used as a reference to know how the results should look like.**

Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.082898	1.017999
60.96	1.082893	1.021462
106.68	1.082869	1.022193
167.64	1.082507	1.020976
335.28	0.973378	0.842685
371,2 (ARI)	0.899009	0.758581

Peach Bottom
Average Axial Power Distribution HZP
Several Control Rod Positions

Peach Bottom
Average Axial Power Distribution HFP
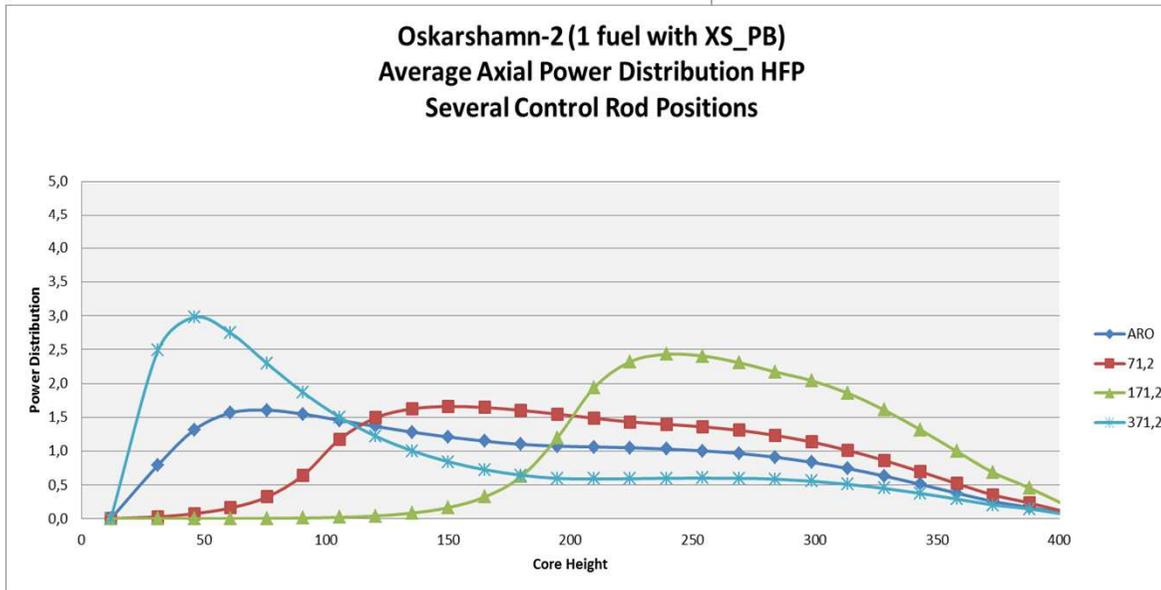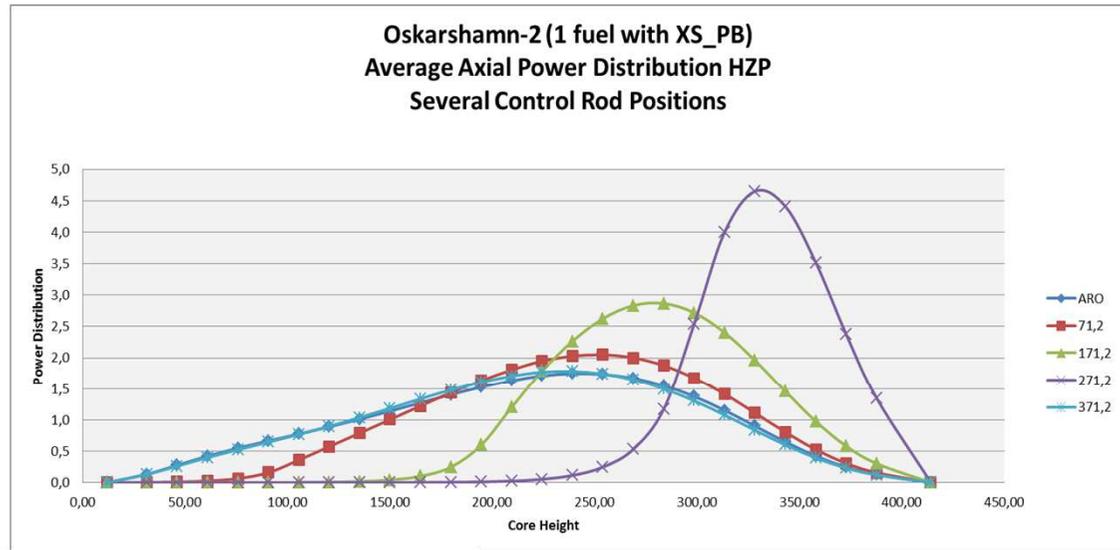Several Control Rod Positions

Case 3
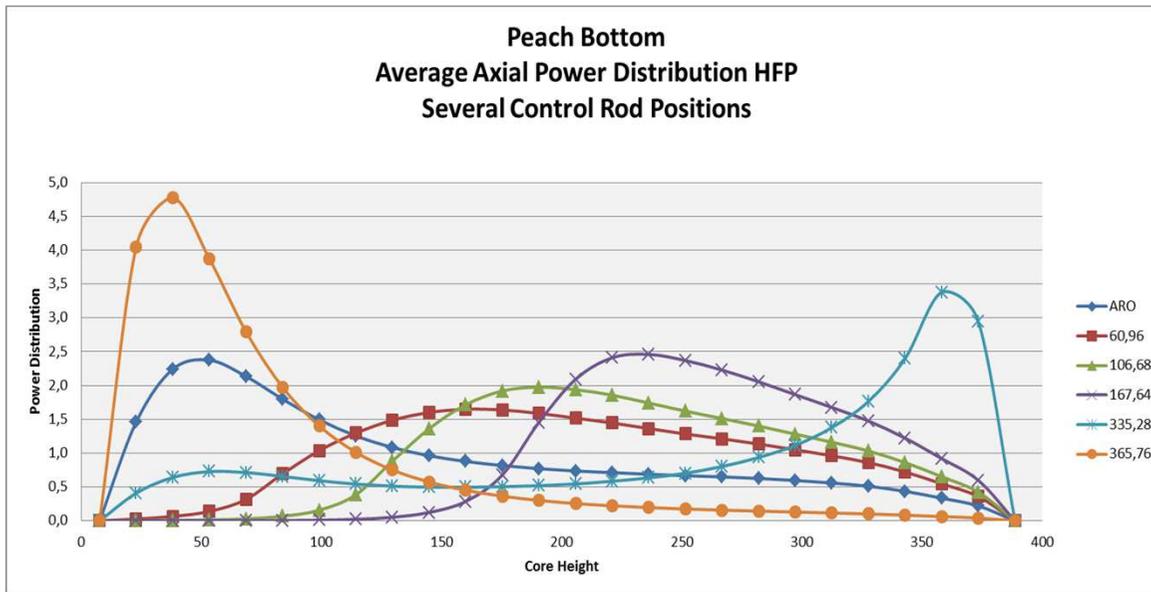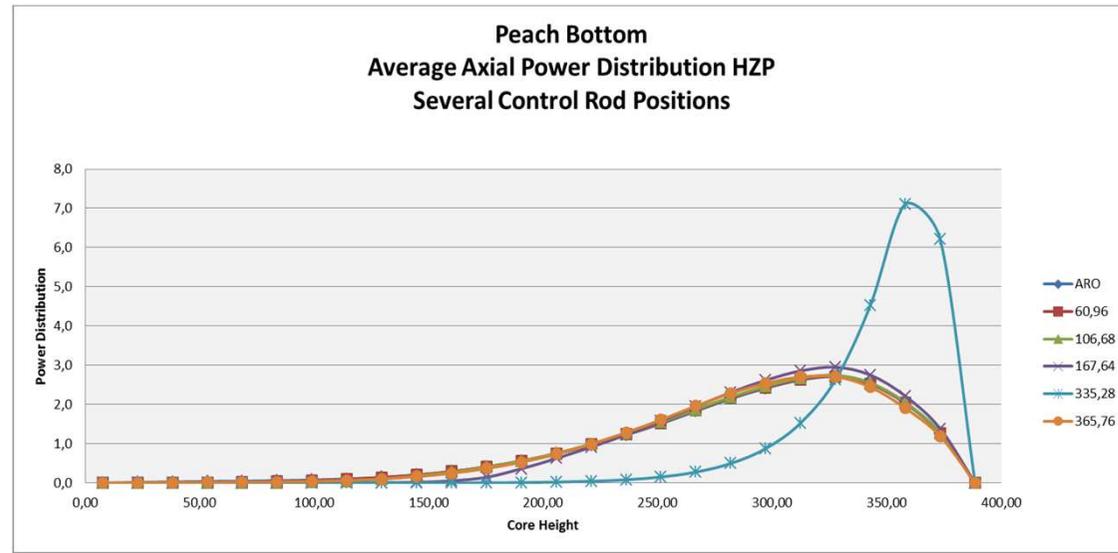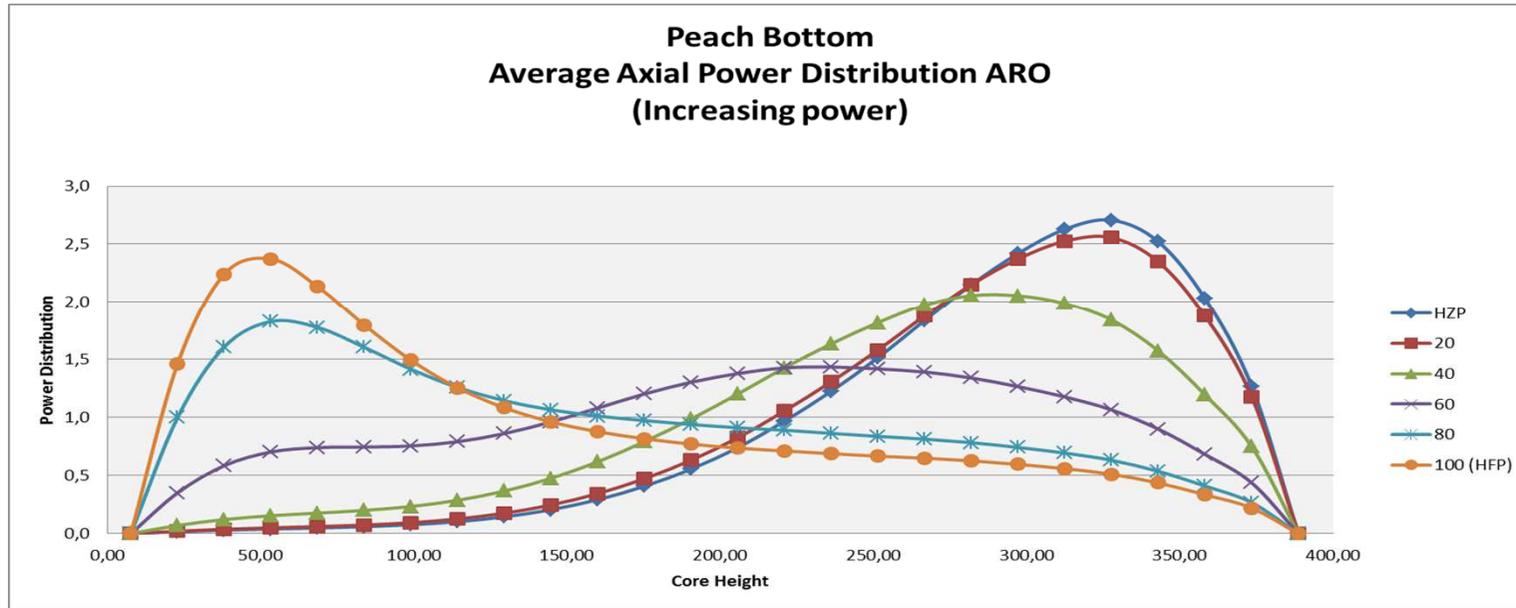
- **DYN3D executed for this case successfully.**
- **The behaviour of axial power distribution as we expected.**
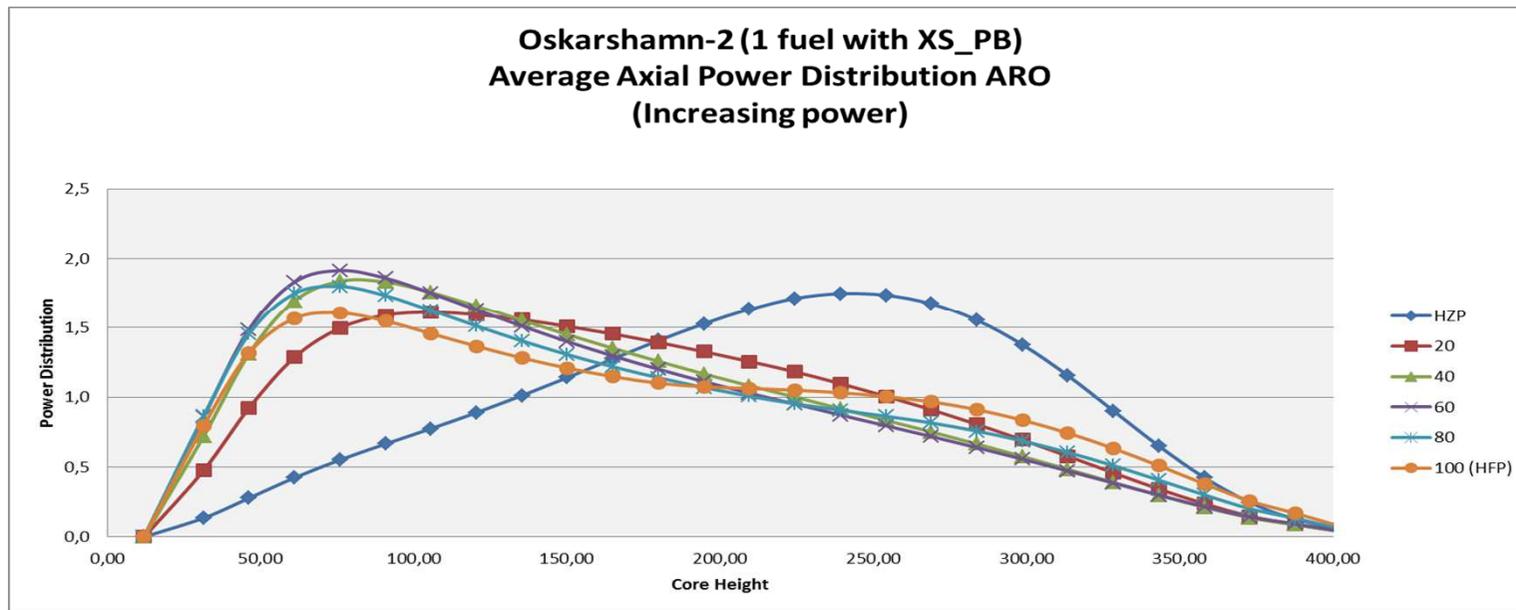
Case 4

- **Input deck for Oskarshamn-2 but considering the XS library of Peach Bottom Benchmark and repeating one fuel assembly in the whole core.**

Elevation	Keff HZP	Keff HFP
0.0 (ARO)	1.172246	1.08452
71.2	1.171262	1.080034
171.2	1.163719	1.066463
271.2	1.113755	NaN
371.2 (ARI)	0.937954	0.752765

Oskarshamn-2 (1 fuel with XS_PB)
Average Axial Power Distribution HZP
Several Control Rod Positions

Oskarshamn-2 (1 fuel with XS_PB)
Average Axial Power Distribution HFP
Several Control Rod Positions

Oskarshamn-2 (1 fuel with XS_PB)
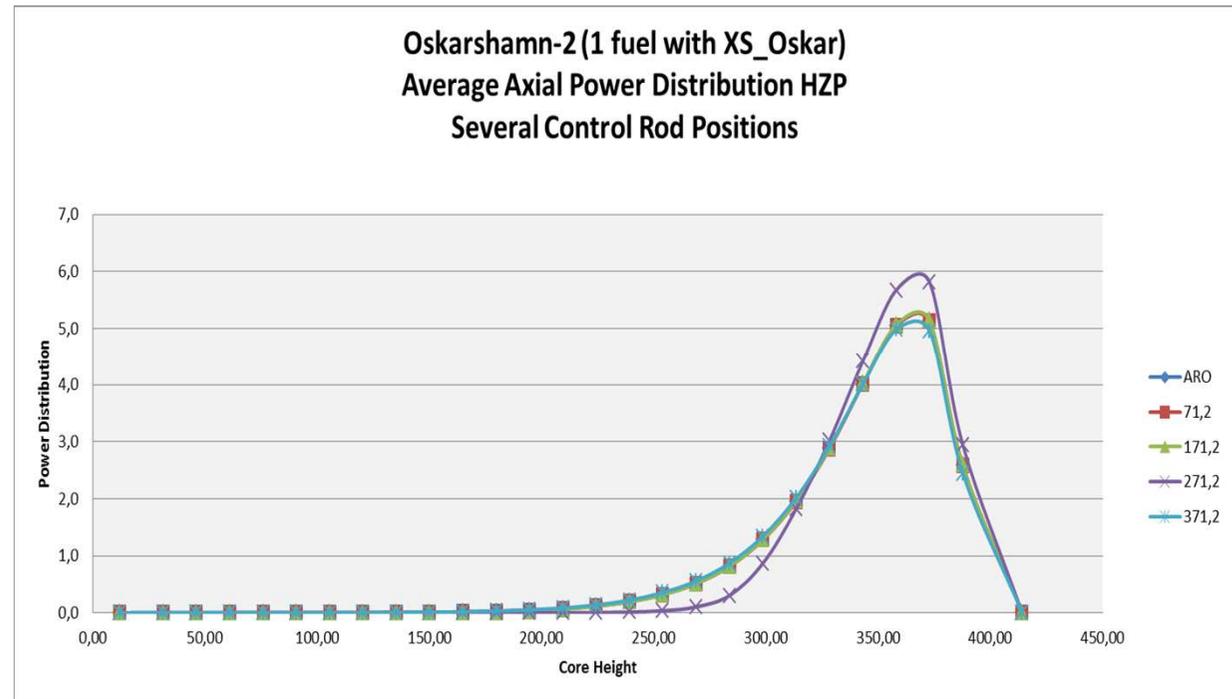Average Axial Power Distribution ARO
(Increasing power)

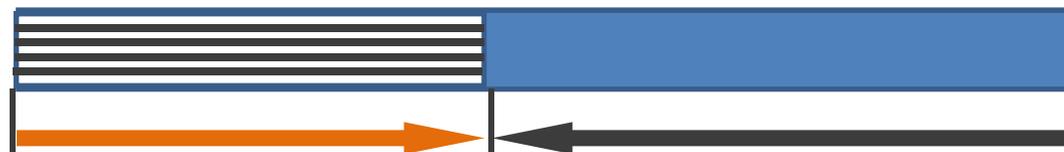- **The behaviour of axial power distribution as we expected.**

Case 5

- **Input deck for Oskarshamn-2 but considering the NEMTAB XS library released and one fuel assembly loaded in the all the core.**

Elevation	Keff HZP
0.0 (ARO)	0.906970
71.2	0.906969
171.2	0.906968
271.2	0.905266
371.2 (ARI)	0.713506

HFP
Calc. Failed

Oskarshamn-2 (1 fuel with XS_Oskar)
Average Axial Power Distribution HZP
Several Control Rod Positions

Bottom of the core   Top of the core

Conclusions and Outlook

- **After the last Oskarshamn-2 OECD/NEA workshop it is clear that the XS libraries are not working properly.**

- **The HZP calculations show a big accumulation of the power distribution in the top of the core.**
  - No TH feedback effect shown using the current XS data.
  - Too high values of the power which produce unphysical temperatures in FLOCAL and extrapolation of the XS.

- **The D13.23 has been released with 5 months delay but with the best data available.**
  - Integrity of the DYN3D input checked using the Peach Bottom Turbine Trip XS data. Properly geometry definition.

FUTURE WORK

- **In the next months:**
  - Waiting for a proper set of XS libraries for the O2 (KTH/PSU?).
  - Next will follow coupled neutronics computations to this model

THANKS FOR YOUR ATTENTION