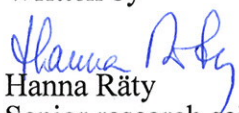




Utilization of the new method and tool for generating neutronics data for TRAB-3D

Authors: Hanna Rätty

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VTT: Daavittila, Hämäläinen, Kotiluoto, Rantamäki, Rintala, Seppälä, Syrjälähti	
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1 Introduction

TRAB-3D /1/ is VTT's three-dimensional reactor analysis code for core geometries with a rectangular lattice. It is widely used for transient analyses for both BWR and PWR reactors.

TRAB-3D is supported by VTT's reactor analysis code system. Reactor physics data for the dynamics codes can be generated starting from the basic nuclear libraries. The cell-burnup code CASMO-4 /2/ is usually used to calculate the cross sections for the three-dimensional core models. Nodal distributions for fuel burnup, void and control rod histories are obtained from fuel management codes, e.g. SIMULATE /3/.

For quick and simple generation of neutronics input data a new procedure has been developed, utilizing the SIMULATE-3 code. The procedure and scripts for preparation of TRAB-3D input data from SIMULATE-3 files have been reported in /4/.

The present report describes the use of the method in TRAB-3D. Changes in TRAB-3D needed in reading and manipulating input data are summarised in /5/.

The work has been carried out in the TRICOT project of the SAFIR2010 Research programme, with the funding of VTT and VYR.

2 Data files with SIMULATE-3 data

For each operating state two temperature and two density perturbations have been made to the base calculations with SIMULATE-3. All the calculations have been made with all rods both inserted and withdrawn. Thus ten SIMULATE-3 calculations have been made for each operating state. The data for each node in the three-dimensional core is collected into three files per operating state that are used as input files for TRAB-3D: two contain the material constants for rodded and unrodded cases and one contains the neutronics input. In addition files are written that contain the Xenon and Samarium concentration in a format readable by TRAB-3D. /4/

The input files produced by SIMULATE-3 are located in a directory ToTrab3D, which contains a subdirectory for each reactor state (e.g. power level) considered. The names of the neutronic data files obey the convention:

AAAAA-BBB-CCC.typ

and the subdirectories are denoted with PBBB, according to reactor states.

The naming conventions are as follows.

AAAAA is an identifier, common to all files, chosen by the user, in the example case this is “trans”.
-BBB is an identifier for the reactor state, e.g. power level 60 for 60 %.
-CCC for the material data files: ari for fully rodded aro fully unrodded state. XEN for Xenon and SAM for Samarium data files.
typ ntr for neutronics data files, trb for Xenon and Samarium data files

An example subdirectory would thus look like this:

```
trans-60-SAM.trb
trans-60-XEN.trb
trans-60-ari.ntr
trans-60-aro.ntr
trans-60.ntr
```

3 Reading of input data

3.1 TRAB-3D neutronics input, principal input group NEUTRO

Data for two keywords must be extracted from a file called AAAAA-BBB.ntr (see above for explanations) and inserted in the TRAB-3D input file:

/NEUTRO/OPTIONS for insertion depths of control rod groups
/NEUTRO/DELAYE for time constants of delayed neutrons.

3.2 3D Nodal model: Principal input groups 9 and 11

Besides the two keywords above, the data from a file called AAAAA-BBB.ntr (see above for explanations) must be inserted in the TRAB-3D input file. The data file contains the keywords:

LAYOUT
POSITN
RODPOS
RODCON
BOUNDR
XSDATA
ASSTYP
END4
LOAD
END5

Keywords LIMITS, ITER, FEEDBK, SIZE in group 9 must be given by the user, as well as the STEADY keyword in group 11.

Note:

At the end of the XSDATA-keyword there has to be an extra slash: normally the keyword is ended with the beginning slash of the next keyword, but without the extra slash the reading of cross section data is not initiated, and a hard to decipher error message follows. Likewise the END4 and END5 keywords assume a slash to follow.

3.3 3D Nodal model: Principal input group 10

The files called AAAAA-BBB-ari.ntr and AAAAA-BBB-aro.ntr (see above for explanations) must be appended together to form the materials' data file. The files contain the following keywords:

CASE
MATER
NOMCON
FITCO
DIFCON
DOPLER
MODER

The ALBEDO keyword is not derived from SIMULATE-3 and has to be evaluated by the user and included manually in the materials' data file.

XENON and SAMARIUM data

The data is given from SIMULATE-3 output in two files AAAAA-BBB-XEN.trb and AAAAA-BBB-SAM.trb, and have to be included into one file (read with unit 25).

In keyword STEADY, give
LDSTAT=2 (equilibrium xenon and samarium)
LPSD=1 (equilibrium concentration of samarium is calculated)
IOPTXS=2 (xenon and samarium concentrations are read from a file).

LPSD is given in keyword STEADY, but actually the present version of the code was found to expect to reread it as the first value in file unit 25, and based on that decides whether or not to read the samarium concentration in addition to the xenon concentration. (To be corrected later.)

Note:

Nodal burnups are in the present version of the SIMULATE-3 scripts not printed out from SIMULATE-3 to TRAB-3D. If burnup dependent data were available elsewhere in TRAB-3D, or burnup dependent models were to be used, burnup values should be printed out and read to TRAB-3D variables.

In the NOMCON record, the variable NHET, number of discontinuity factors is intended to be 4 (explanation four per energy group in the Users' Manual might lead to erroneously giving the total number 8). This will be clarified in the next version of the manual.

The subroutine binput performing the reading of TRAB-3D input does not read exponentials given with a lowercase e, a capital E has to be given.

The present version of the input manual does not indicate the order in which the discontinuity factors should be given. They are given starting from top right corner of an assembly, in the order west-south-east-north.

4 Modelling changes in TRAB-3D

4.1 Dimensions

For the materials' data to be given to each node separately, the dimension of materials IDMAT must be large enough (example 25 nodes, 250 channels, rodde and unrodde data -> 12500. Compare with an earlier value: 100). To conserve computer memory, a parallel system of tabulated cross sections was reduced to minimal space by replacing MAXTAB = 14688 -> 1.

It was found out, that the first cross sections were for some unknown historical reason stored under dimension 2, and IDMAT needed to be 12500+1. A place from which this initiated was localized, but it is not totally clear if a correction with the same logic would be needed elsewhere, too, as the code obviously has been working fine in this respect, and this feature was left as it is for now.

Note check the discontinuity factor calculation, if SIMULATE-3 is calculations are used to produce PWR data in future.

4.2 Neutronics data

A new option NXSDAT = -4 in keyword /XSDATA (Section 9.11) will initiate the reading of the neutronic data file derived from SIMULATE-3 calculation.

Neither the energy released per fission, indicated with ϵ in TRAB-3D or κ in SIMULATE-3, nor the neutrons released per fission, ν , can be obtained from SIMULATE-3, and some manipulation of input data was needed in TRAB-3D.

In the SIMULATE-3 scripts for keyword DIFCON (Section 10.4), instead of fast and thermal fission cross section Σ_{f1} and Σ_{f2} the fast and thermal fission production cross sections $\nu\Sigma_{f1}$ and $\nu\Sigma_{f2}$ have been written twice, and instead of κ (or ϵ), κ/ν has been written. To counter this, the subroutine params of TRAB-3D was slightly changed to manipulate the data in such a way that internally for the table XNOM (K,J,I)

	normally		SIMULATE-3 data
XNOM(K,J,8) = XNOM(K,J,9)	$1/\nu$	→	ϵ/ν
and			
XNOM(K,J,10)	ϵ	→	1.

4.3 Discontinuity factors

The code was programmed to assume the discontinuity factors to be calculated by CASMO, and manipulated the values given in input accordingly in subroutine rodpos. For data derived from SIMULATE-3 calculations this feature is now behind the same input option as reading of neutronics data

The next charts in Figures 2...21 show, in subgroups of four figures, the following quantities:

- relative fission power of fuel bundles, radial chart
- relative fission power, vertical distribution at central axis
- mass flow (kg/s) at core inlet, radial chart
- average void fraction, radial chart
- average temperature of fuel (K), radial chart

The subgroups consist of

- TRAB-3D results
- SIMULATE-3 results
- ratio of TRAB-3D and SIMULATE-3 results
- difference of TRAB-3D and SIMULATE-3 results

In some quantities the relative difference in the results looks large, but the absolute values shown in the figures illustrating the difference between the results of the two codes are small.

Figures 2...5 show the relative fission power in the fuel bundles. The results of the two codes are close to each other, with the exception of some bundles close to core periphery. The absolute differences even there are small, however. In general the difference is around 1 %.

Figures 6...9 show the vertical distribution of relative fission power at the central axis of the core. In the TRAB-3D results (axial offset 21 %) the axial power is more downward peaked than in the SIMULATE-3 results (axial offset 20 %). This is most probably due to different axial boundary conditions. The average axial power distributions are shown in Figure 22.

Figures 10...13 show the radial distributions of mass flow at core inlet. The results are very close to each other. TRAB-3D calculates somewhat larger bundle flows for the lone Atrium bundles in the innermost inlet throttling region. Also in the outermost regions the bundle flows are larger than in SIMULATE-3 results, but the absolute values are smaller. Overall the differences are mostly of the magnitude 0.2 kg/s per bundle, which is not a bad result, considering that TRAB-3D does not presently have a model for internal water channels in a bundle, and this is taken into account in an approximative manner.

Figures 14...17 show the radial distribution of the average void fraction in fuel bundles. A few bundles with a large relative difference distort the comparison chart, but looking at the absolute difference the values are seen to be small.

Figures 18...21 show the radial distribution of average temperature of fuel in fuel bundles. Here the differences in fuel data are seen. The temperatures calculated by TRAB-3D are lower than those calculated by SIMULATE-3, but 0...60 K. This is not surprising, considering the inaccuracies of material data in the test case.

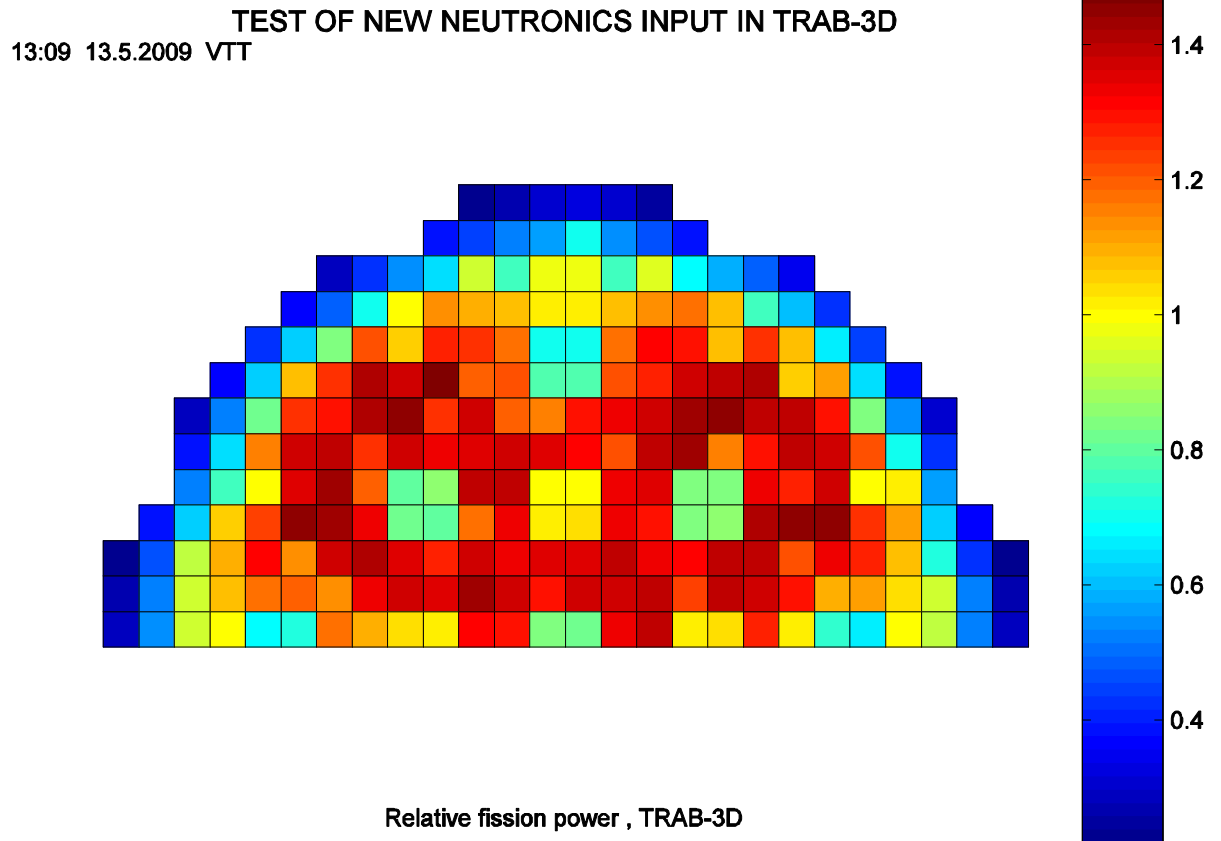


Figure 2.

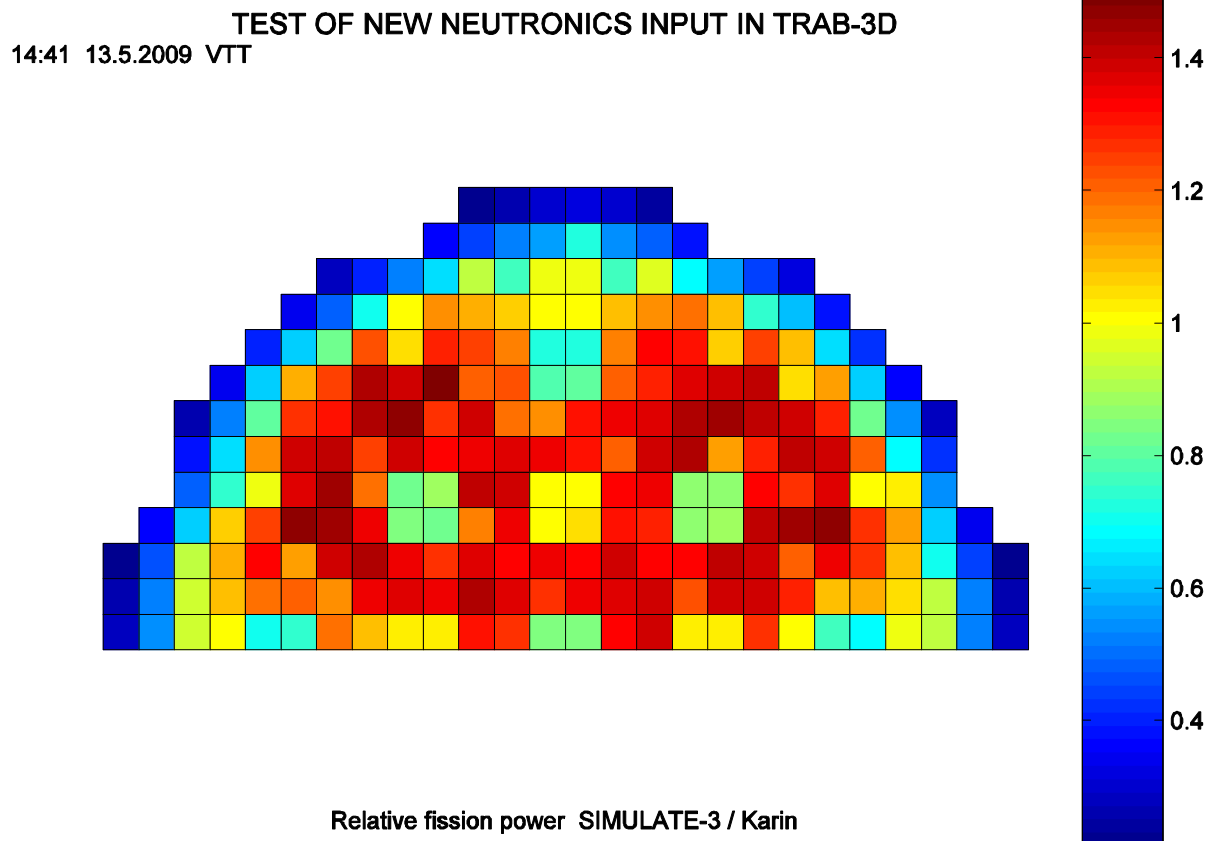


Figure 3.

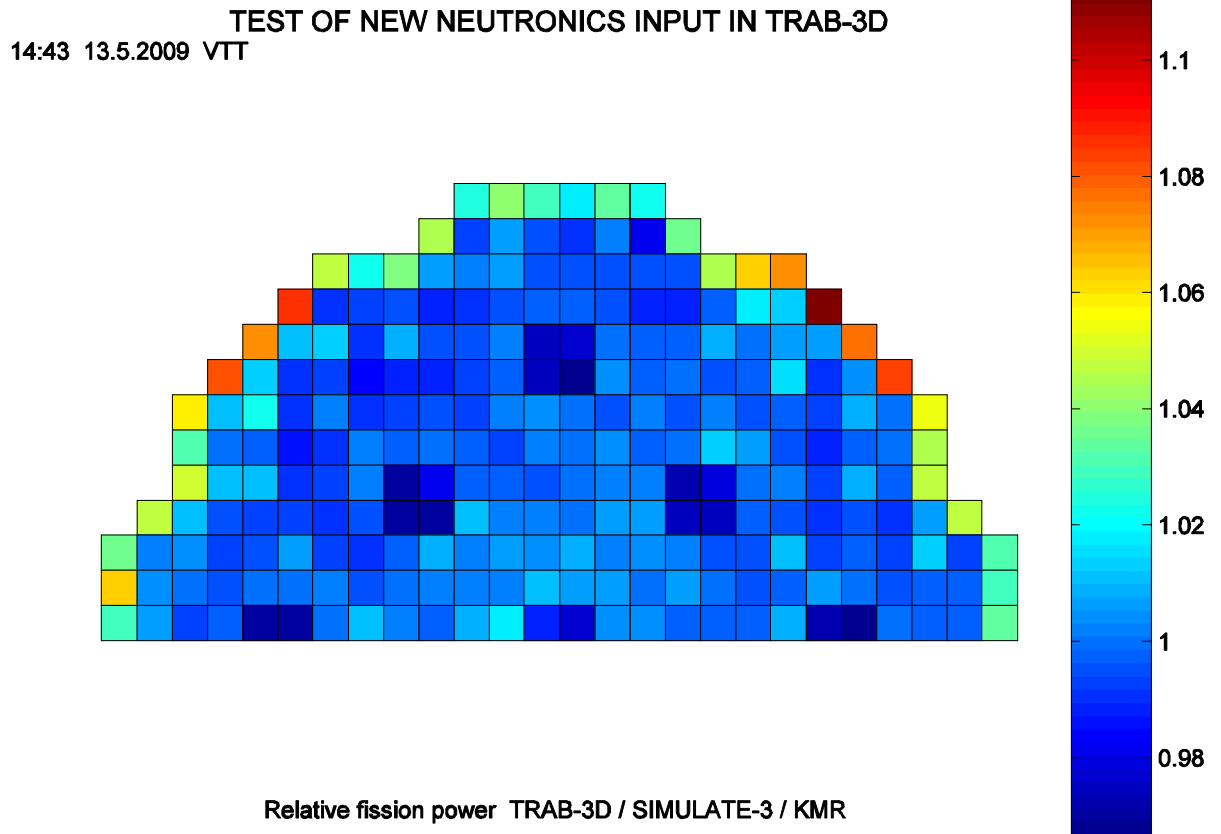


Figure 4.

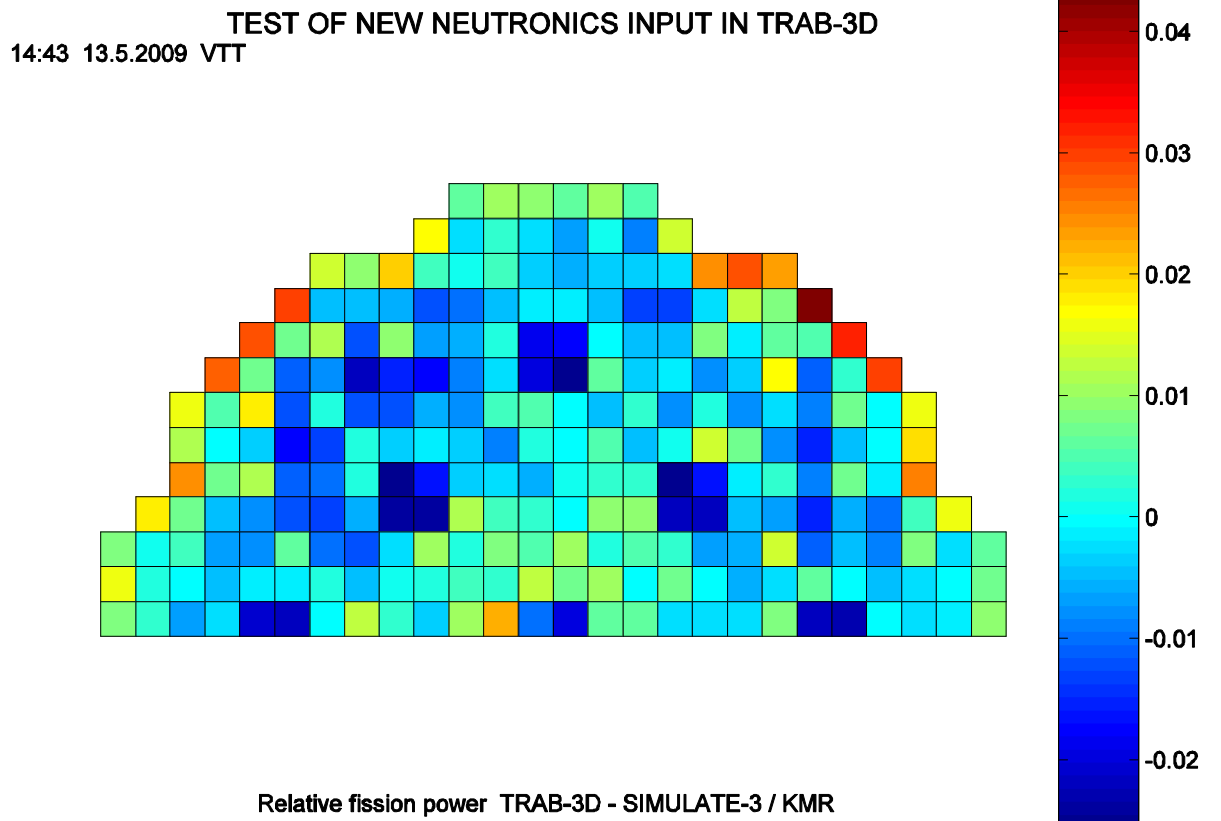


Figure 5.

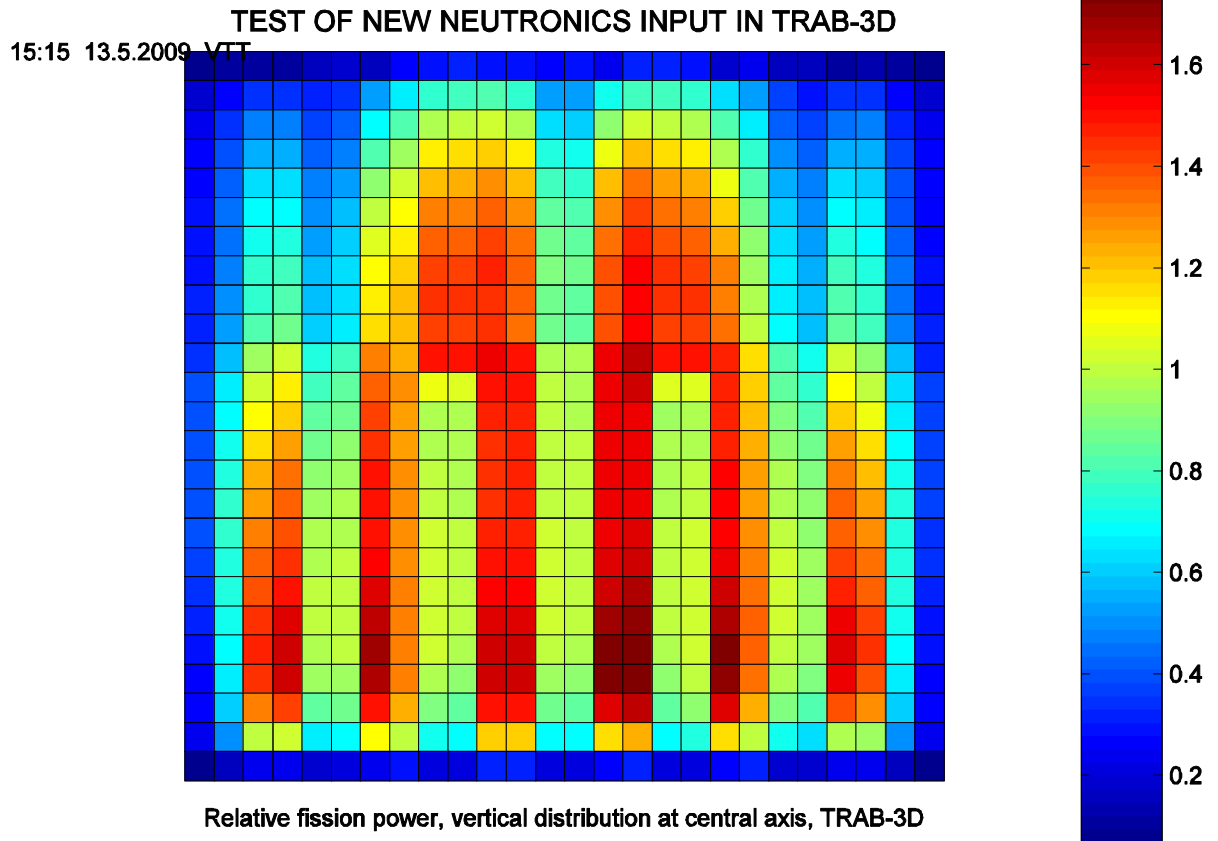


Figure 6.

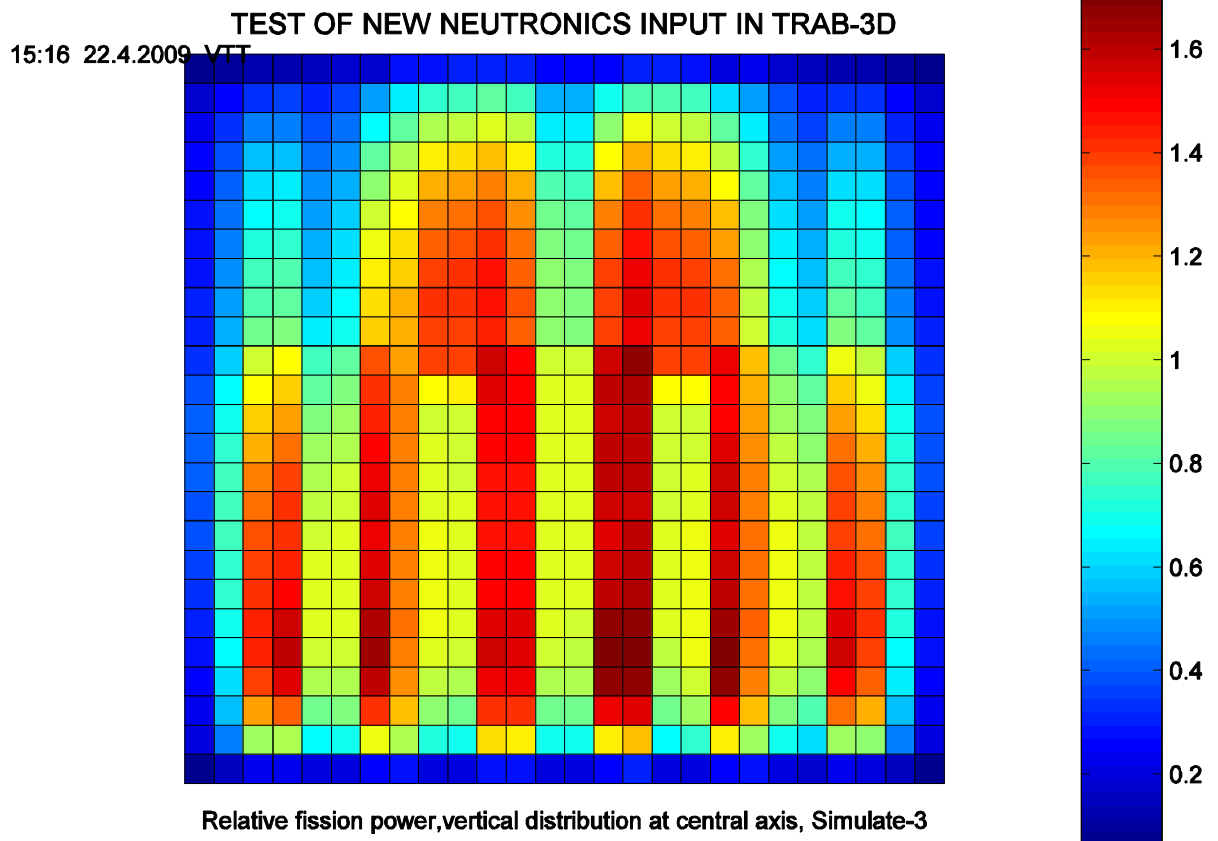


Figure 7.

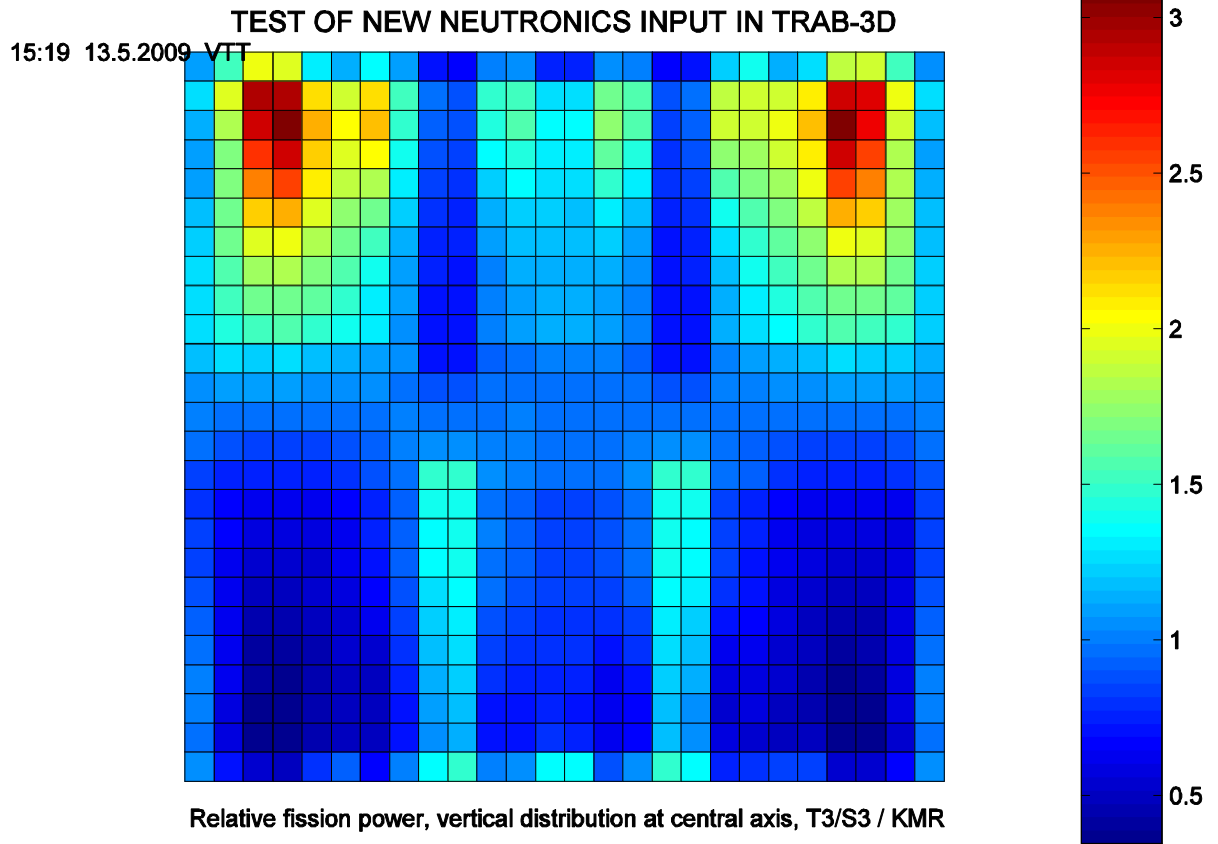


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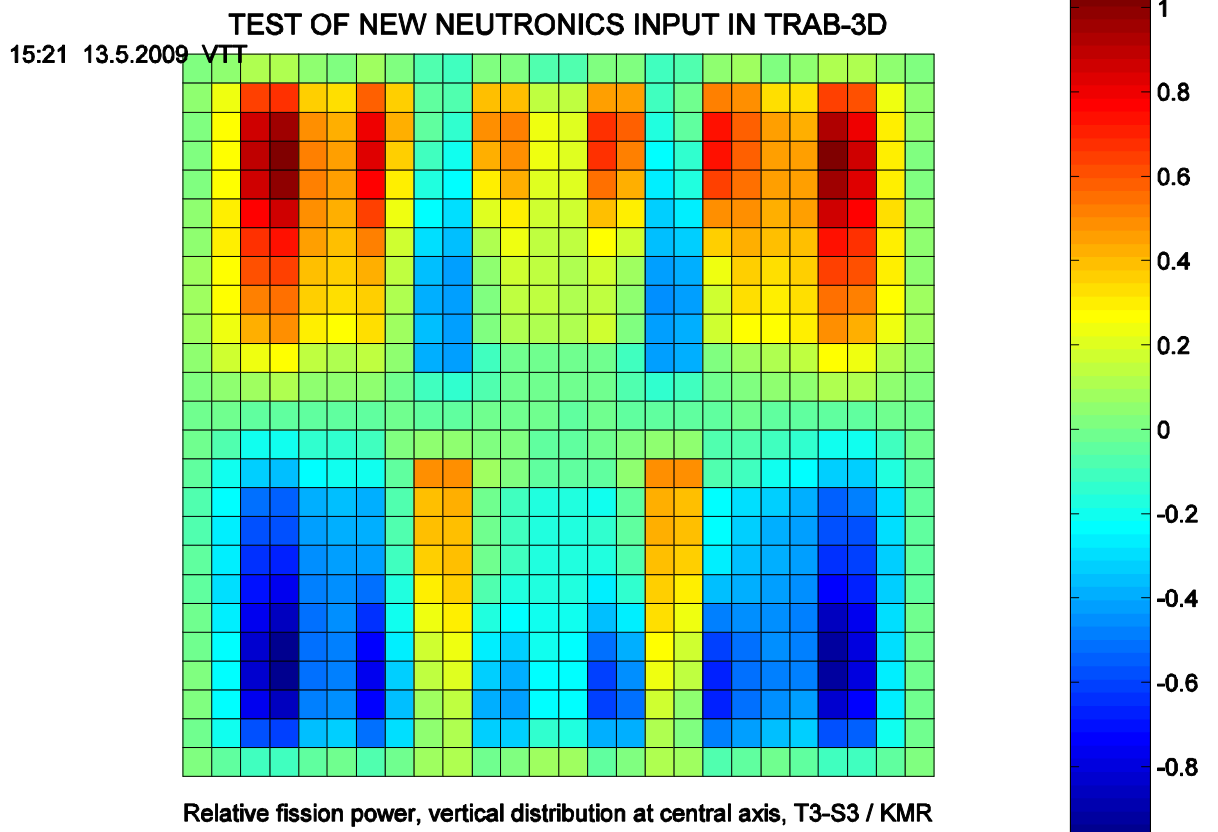


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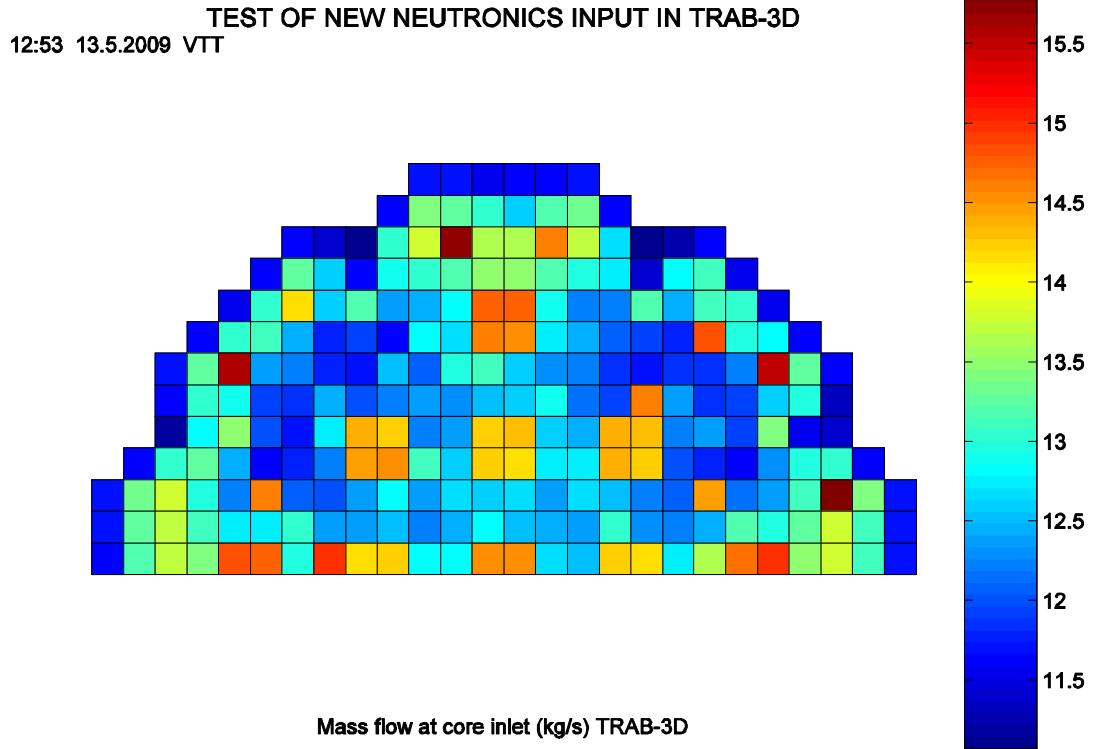


Figure 10.

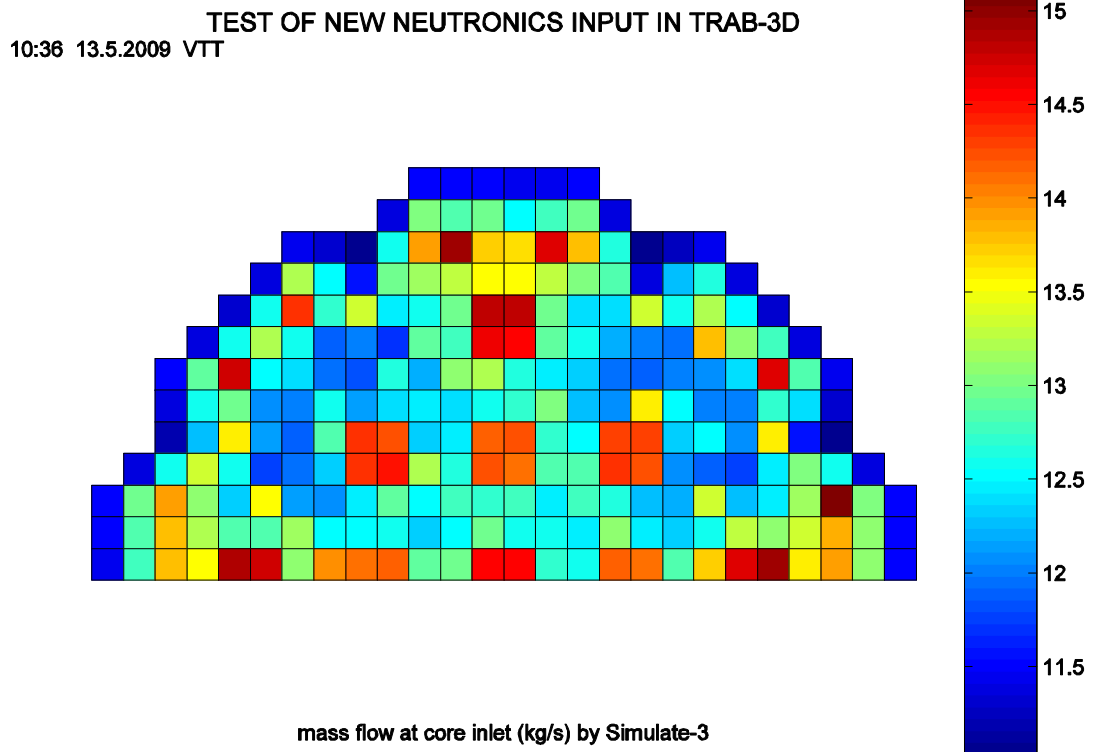


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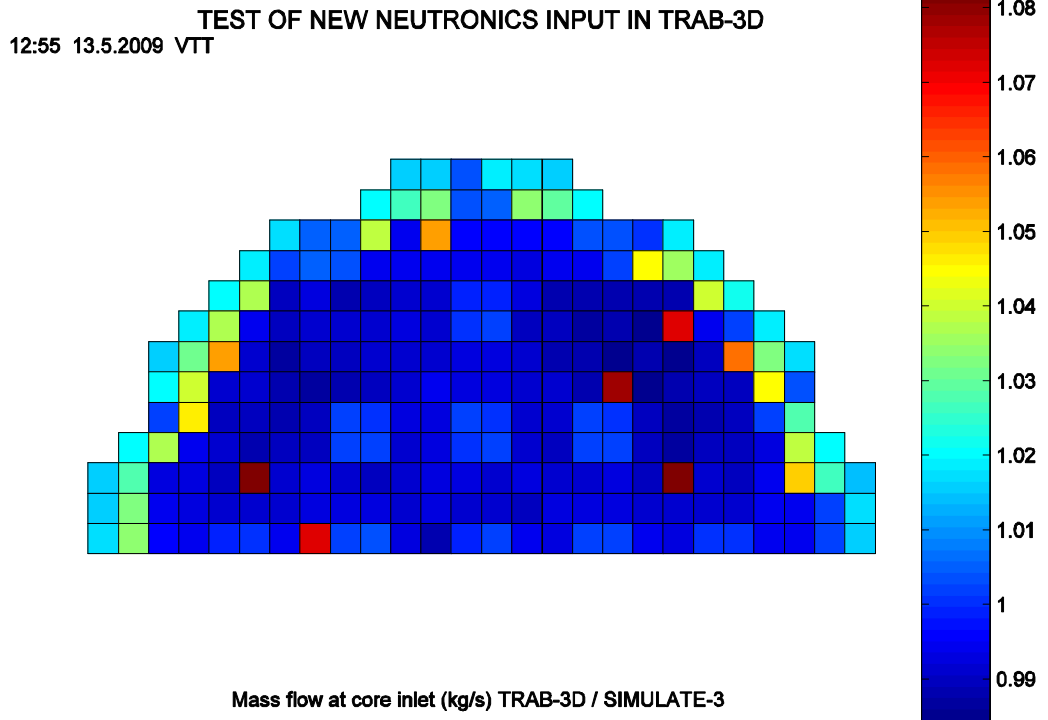


Figure 12

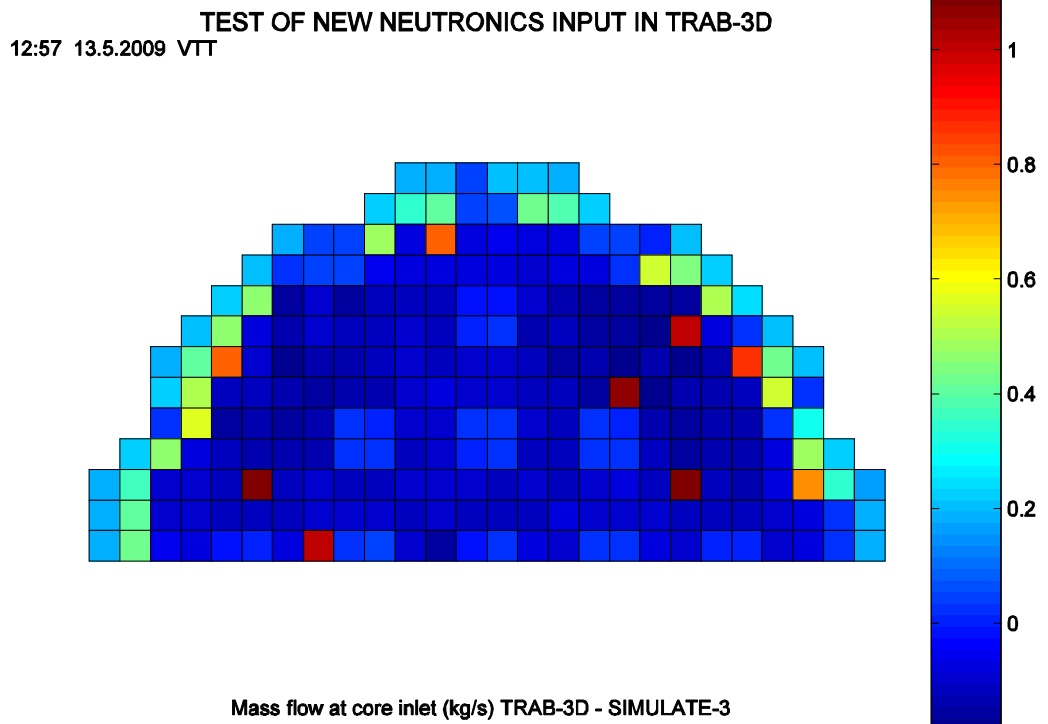


Figure 13

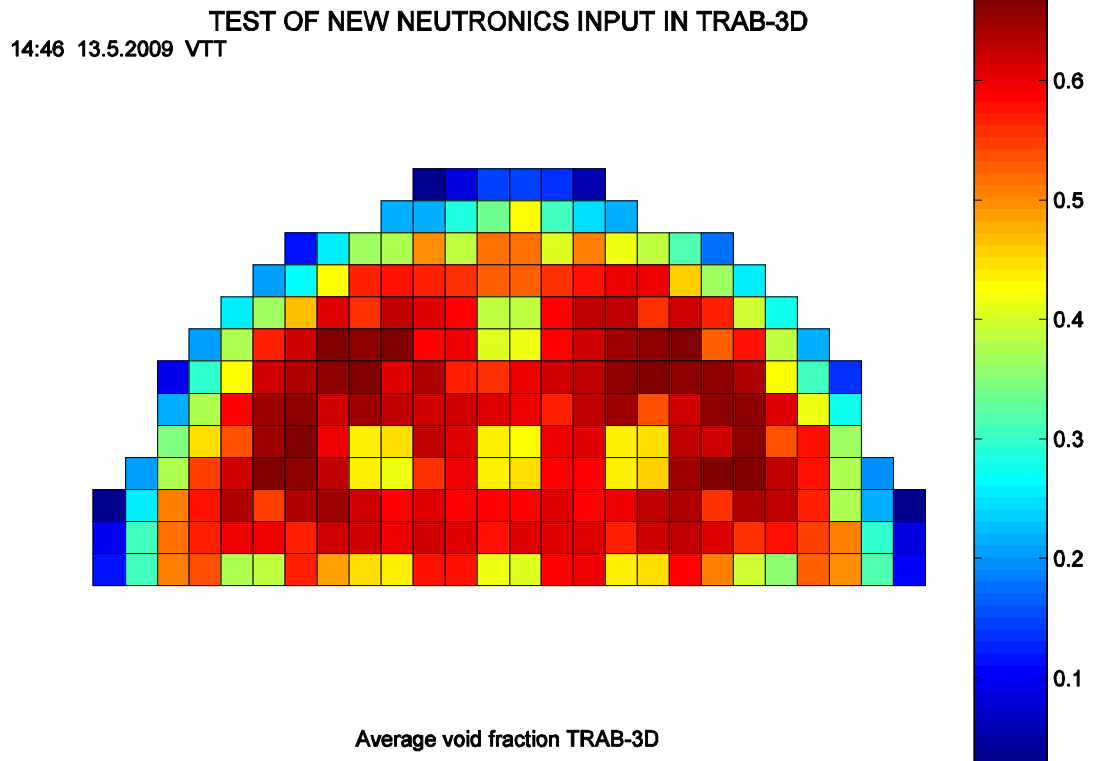


Figure 14.

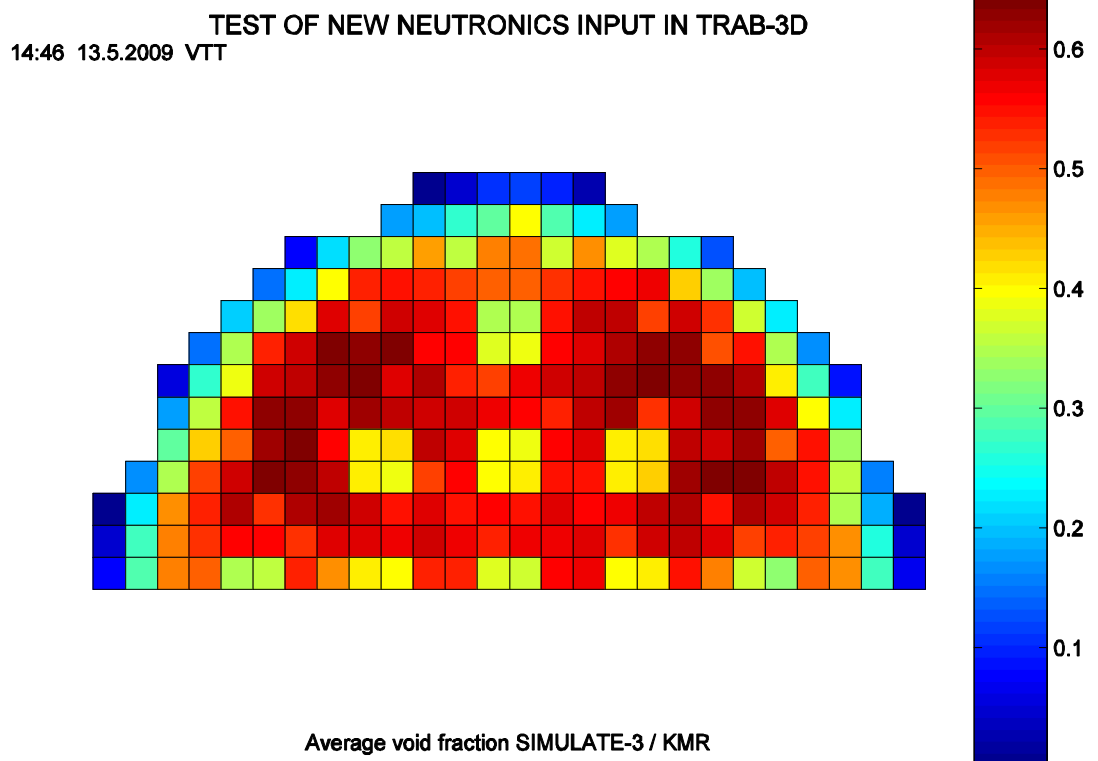


Figure 15.

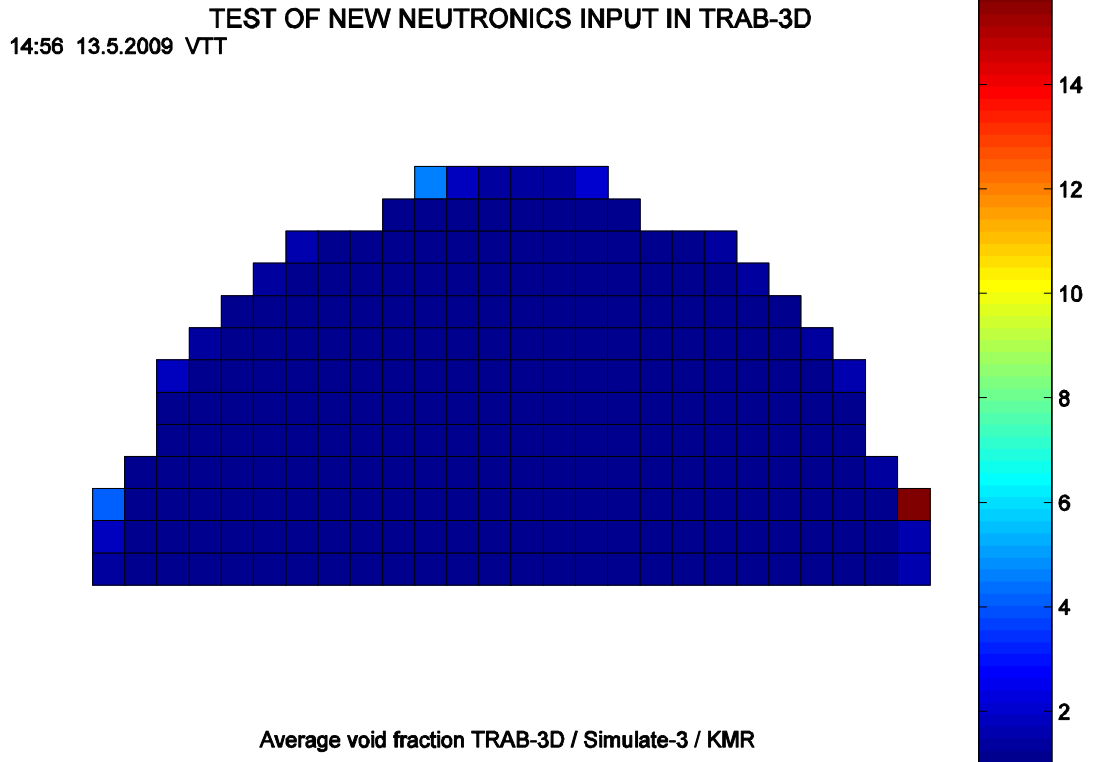


Figure 16.

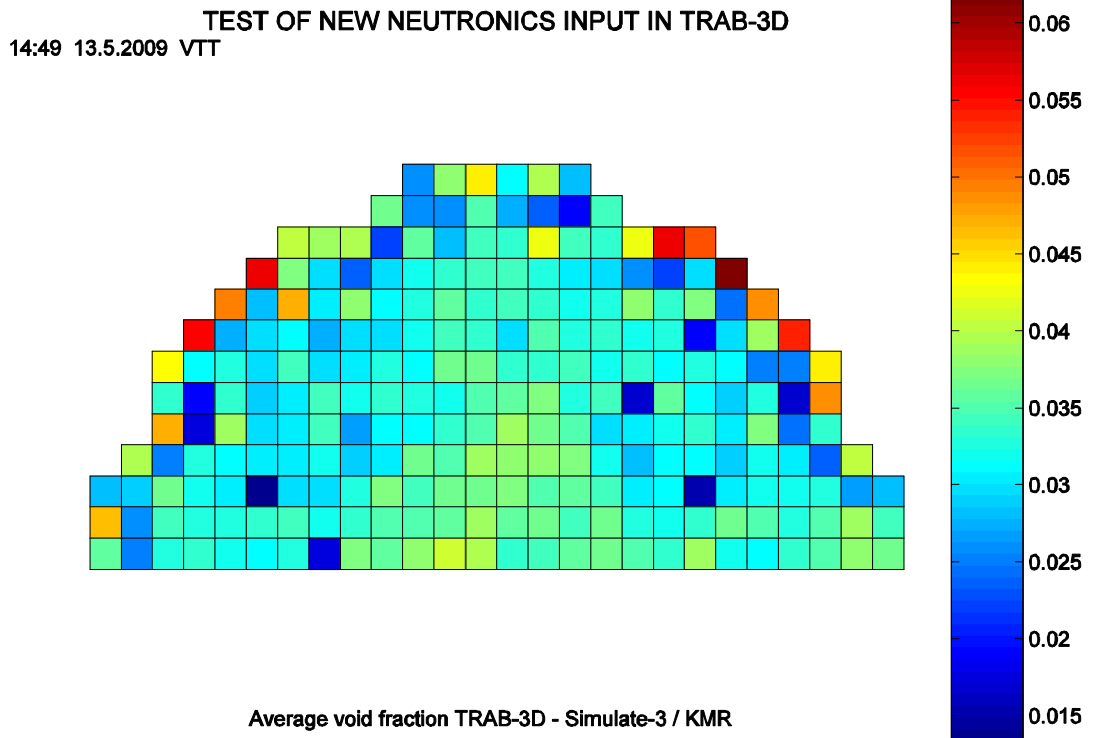


Figure 17.

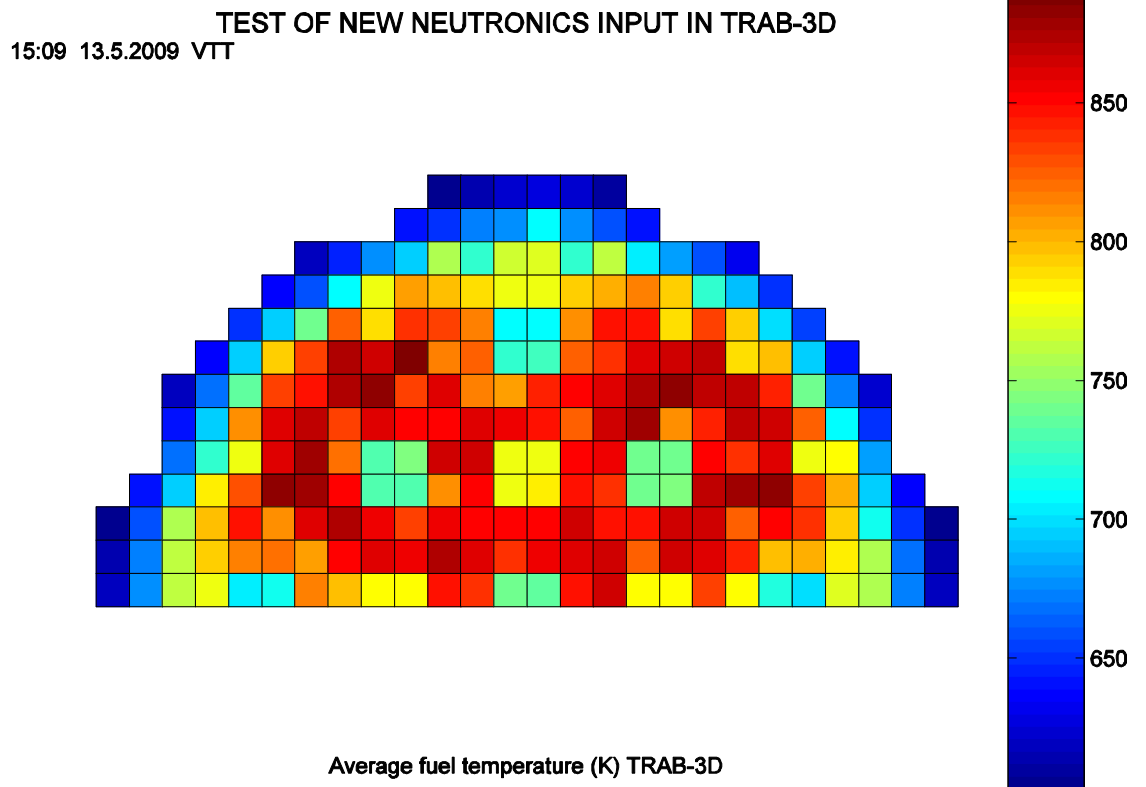


Figure 18.

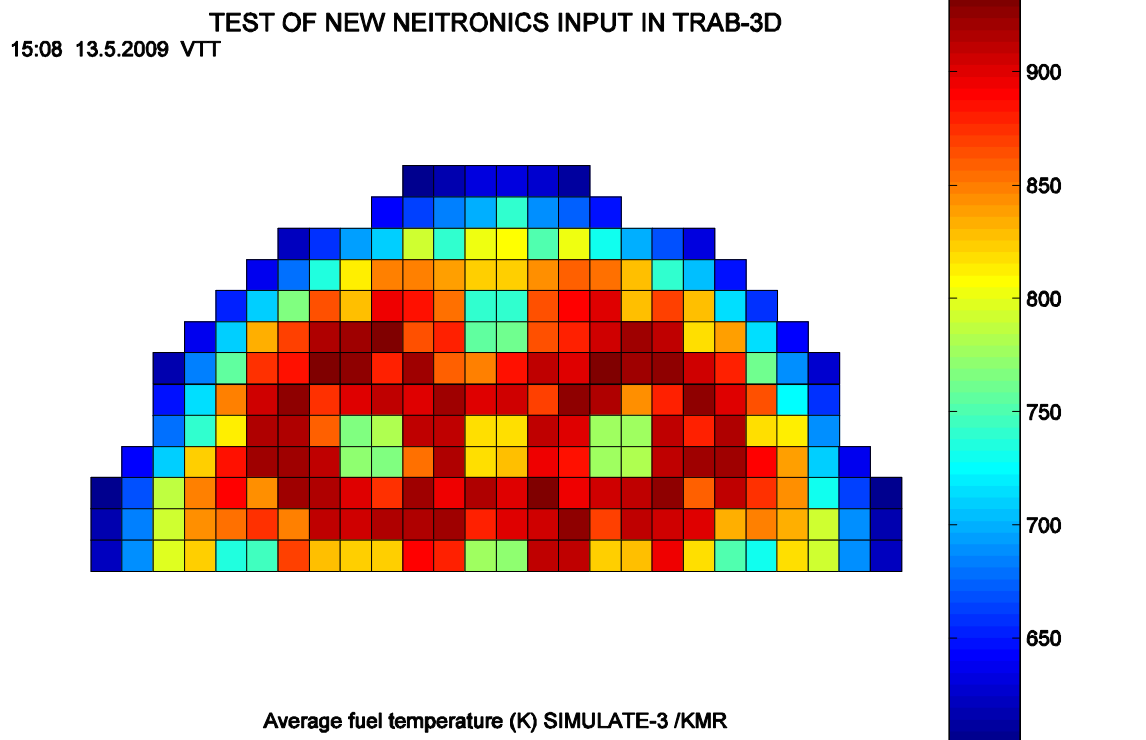


Figure 19.

TEST OF NEW NEUTRONICS INPUT IN TRAB-3D
 15:10 13.5.2009 VTT

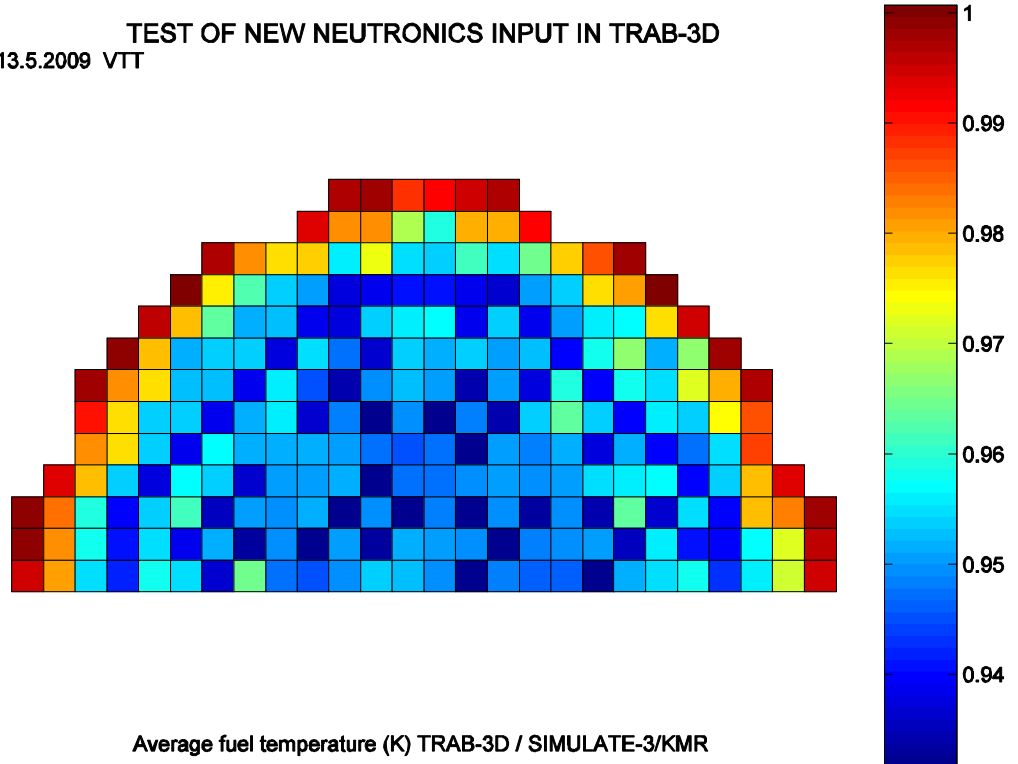


Figure 20.

TEST OF NEW NEUTRONICS INPUT IN TRAB-3D
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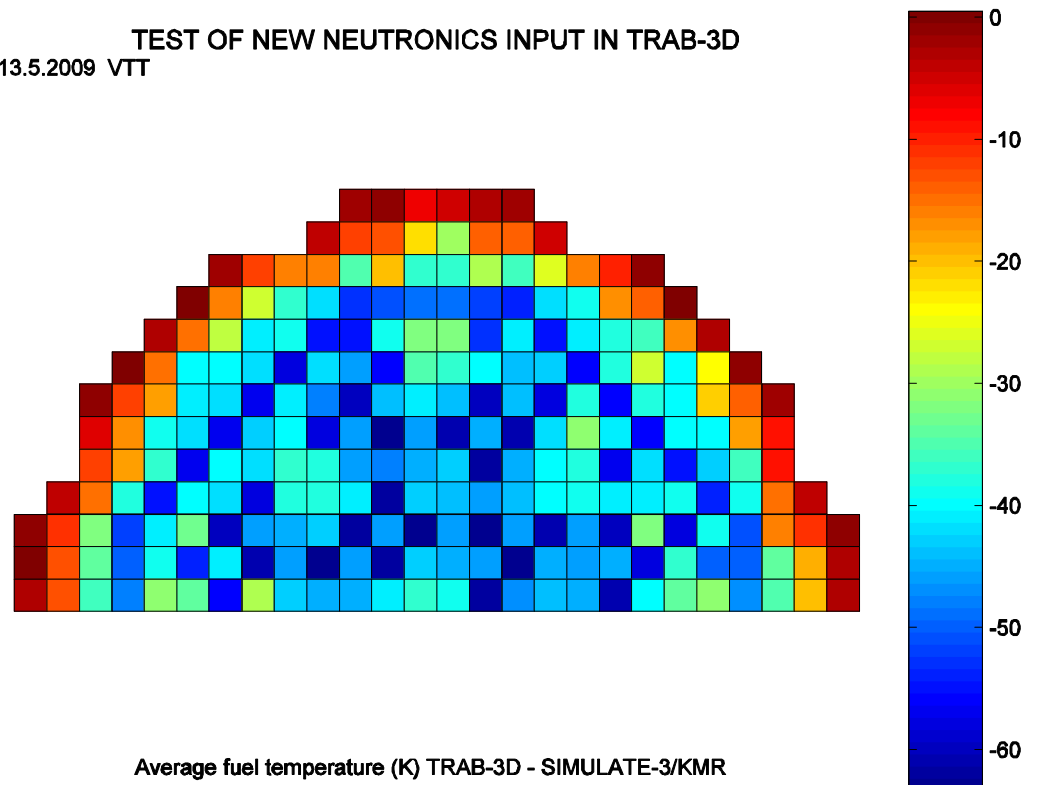
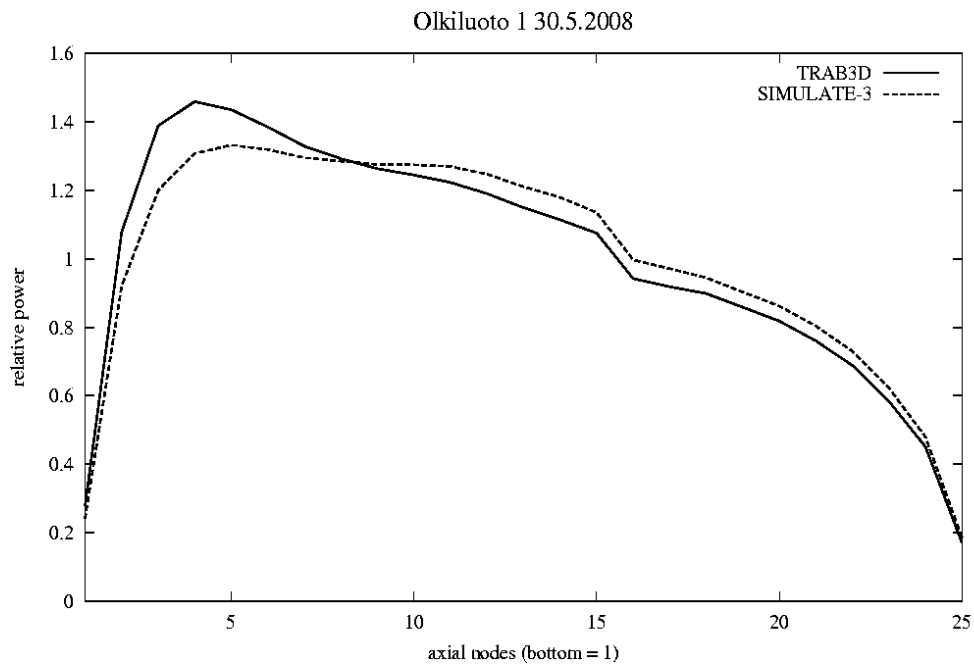


Figure 21.



Average axial power in steady state with TRAB-3D and Simulate-3

13/05

Figure 22.

6 Conclusions

A quick and simple procedure for generation of neutronics input data for VTT's three-dimensional reactor analysis code TRAB-3D has been taken into use. The procedure utilizes data calculated by Studsvik Scandpower's SIMULATE-3 code. Only minor modifications to the TRAB-3D code and its input were needed.

Steady state comparisons between results of TRAB-3D and SIMULATE-3 were carried out, confirming that the differences between the results of the two codes are mostly small, even without any harmonising the models, or explained by the differences in modelling or initial data.

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