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UKAEA development of the JADE tool for V&V of nuclear data and particle transport codes

Alex Valentine, Steven Bradnam, Dylan Wheeler + JADE development team FENDL Consultants' Meeting, 01.11.23

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Changing landscape for particle transport codes



Investigation of alternative codes

- MCNP is the reference transport code for fusion neutronics. It is heavily validated and well developed over the course of 40 years...
- Many patches for the code have been developed built on requirements for fusion neutronics and bugs that have been found. For most problems, it does what we want, and reasonably well.
- Alternatives to MCNP have emerged, particularly over the last ~10 years. UKAEA has actively
 investigated their potential application to fusion.



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Motivation – Integrated engineering

 MCNP - single user, single site license is required, ~£1000 +. If running on computing network, system administrators are required to hold a license.

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- In the design of fusion reactors, we need integrated multi-physics simulations capable of rapid exploration of a broad design space. Modern day advances in computing must also be harnessed.
- The deployability and accessibility of OpenMC has allowed development of such tools -UKAEA has developed AURORA code, coupling neutronics and thermal-mechanical FEA analysis (see <u>https://github.com/aurora-multiphysics/aurora</u>, H. Brookes et al.). Can be used for creating digital twins for test facilities – a key need for commercialization.



AURORA: A Unified Resource for OpenMC (fusion) Reactor Applications Simulation of HCPB blanket concept

Advanced modelling







Advanced modelling







JADE V-V tool

Extending the capability of the tool

[1] Davide Laghi, Marco Fabbri, Lorenzo Isolan, Raul Pampin, Marco Sumini, Alfredo Portone, Andrej Trkov, JADE, a new software tool for nuclear fusion data Official

libraries verification & validation, Fusion Engineering and Design, Volume 161, 2020, https://doi.org/10.1016/j.fusengdes.2020.112075.

The JADE tool for V&V

- JADE¹ is an **open source** python based tool for the validation and verification of nuclear data libraries (see talk by D.Laghi).
- The windows application provides a set of computational and • experimental benchmarks that are performed using MCNP for given nuclear data libraries, with extensive output for analysis and examination of results.
- Recent application demonstration for JEFF-4T2 and FENDL-3.2.
- UKAEA have been contributing to the development of the tool ٠ with the following primary objectives:
 - **Develop a Linux compatible version**
 - Restructure JADE to include additional transport codes
 - **Develop workflow for submission in parallel**
- For the initial proof of principle, we have been using the 'sphere' • leakage' computational benchmark included in the JADE.













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Execute Simulations in Parallel

Linux compatible version of JADE

- Dependency handling is now managed by *pip* rather than *conda*:
 - Re-configured as a command line tool that can be called with single command line argument, 'jade'.
 - Removed the dependency on *conda*, allowing any python3 installation to be used.
- Windows-only packages have been removed.

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- Alternative multiplatform packages were implemented where needed.
- As much as possible, retain original JADE functionality. Tool must be able to run on both platforms

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(jade) avalenti@freia032> jade

Welcome to JADE 3.0.0 A nuclear libraries V&V Test Suite Release date: 10/05/2022

MAIN MENU

Powered by NIER, UNIBO, F4E, UKAEA

Open	Quality check menu	(qual)
Open	Computational Benchmark menu	(comp)
Open	Experimental Benchmark menu	(exp)
Open	Post-Processing menu	(post)

UTILITIES

* Print available libraries	(printlib)
* Restore default configurations	(restore)
* Translate an MCNP input	(trans)
* Print materials info	(printmat)
* Generate material	(generate)
* Switch fractions	(switch)
* Change ACE lib suffix	(acelib)
* Produce DIS Reaction file	(react)
* Remove all runtpe files	(rmvruntpe)
* Compare ACE/EXFOR	(comparelib)

* Exit

Enter action:

Modifications to configuration files

• Configuration file extended to OpenMC and Serpent.

Computational benchmark additional options

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Default Benchmarks

Description	Folder Name	OnlyInput	MCNP	Serpent	OpenMC	d1S	Post-Processing	NPS cut-off	Custom Input
Sphere Leakage Test	Sphere	true	true	true	true	false	true	1.00E+06	10
ITER 1D (by M. Sawan)	ITER_1D	false	false	false	false	false	true	5.00E+07	
Helium Cooled Pebbled Bed Test Blanket Module (1D)	HCPB_TBM_1D	false	false	false	false	false	true	1.00E+07	
Water Cooled Lithium Lead Test Blanket Module (1D)	WCLL_TBM_1D	false	false	false	false	false	true	1.00E+07	
C-Model R181031 rev190715	C_Model	false	false	false	false	false	false	1.00E+08	
ITER Cylindrical benchmark for SDDR	ITER_Cyl_SDDR	false	false	false	false	false	false	5.00E+08	
Sphere SDDR	SphereSDDR	false	false	false	false	false	false	1.00E+08	

Experimental benchmark additional options

Default Benchmarks									
Description	Folder Name	OnlyInput	MCNP	Serpent	OpenMC	d1S	Post-Processing	NPS cut-off	Custom Input
Oktavian Experiment	Oktavian	false	false	false	false	false	true	1.00E+07	
Frascati Neutron Generator SDDR experiment	FNG	false	false	false	false	false	false	5.00E+08	



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Running JADE in parallel

- To perform validation and verification optimally for a large number of benchmarks and for complex geometries, HPC systems should be utilised for parallel submission of Monte-Carlo simulations.
- JADE can now be run either on the command line or submitted as a job. Demonstration on LoadLeveler submission system on the UKAEA 'freia' HPC cluster and other UKAEA workload managers (i.e. SLURM).
- In principle, any workload manager can be supported by creating a template job submission file deployment on Marconi or CSD3 (UK HPC centre) for example.

1	#!/bin/sh
2	
3	₽#SBATCHjob-name="JADE"
4	#SBATCHworkdir=INITIAL_DIR
5	#SBATCH output=OUT_FILE
6	#SBATCHerror=ERROR_FILE
7	#SBATCHmem-per-cpu=8000
8	#SBATCHtime=16-48:00
9	L#SBATCHntasks=MPI_TASKS
10	
11	CONFIG_SCRIPT
12	
13	ENV_VARIABLES
14	
15	COMMAND

MAIN C	ONFIGURATION VARIABLES
MCNP executable	/home/mcnp/mcnpexecs/drake/mcnp6v2_ifort2018_n1s
MCNP config	mcnp_config.sh
Serpent executable	/home/avalenti/software/freia/Serpent2_src/v2.1.32_ccfe/sss2
Serpent config	serpent_config.sh
OpenMC executable	/home/avalenti/software/openmc_0.13.3/build/bin/openmc
OpenMC config	openmc_config.sh
d1S executable	
d1S config	
OpenMP threads	1
MPI tasks	8
Batch system	sbatch
Batch file	Job_Script_Templates/Slurmtemplate.sh

Handling multiple transport codes

- For all transport codes, we need an accurate representation of the geometry, source term and physics.
- csg2csg¹ and are openmc_mcnp_adaptor used for conversion of geometry and materials for all current JADE benchmarks.
- Simple source terms manually replicated. For FNG, we have developed a wrapper to the MCNP source routine in OpenMC and Serpent. Material definitions for each code handled using *XsdirTable* object and developed material card writers for Serpent and OpenMC.
- Nuclear data: OpenMC uses HDF5 format nuclear data [see <u>https://openmc.org/official-data-libraries/</u>]. Distributed by FENDL? Serpent and MCNP equivalent ACE files.
- Different implementations for tallies:
 - OpenMC does not support surface flux tallies.
 - ➢ F4 + tally multiplier only applicable to MCNP.
 - Serpent only supports single isotope entry for reaction rates.
 - Different normalisations/units for each code post processing must handle.
- Unique implementations for variance reduction.
- For the sphere benchmark, the inherent differences between the codes mean a direct translation of the full MCNP benchmark model cannot be achieved.

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Post-processing development

Current development status

• New output parsers have been developed for OpenMC and Serpent, minimizing dependencies.

Example of a cross library comparison of neutron flux for MCNP in the sphere leakage benchmark.



Leakage Neutron Flux (175 groups)

Energy [MeV]



Post Processing



Post processing

- The Excel outputs provide a powerful visualization for analysis and interpretation. This has been preserved on Linux. No changes to A*tlas* files.
- Previous, *xlwings* dependency removed. Rather than using template files, now create and write Excel file containing the post processed data using pandas and *XLSXwriter*.

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	ZA	AID					TALLY								
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	1001	H-1	-0.001924221	-0.00135666	0.000394808	0.001129611	9.9442E-05	0.000690478	0.000637707	0.00021077	0.000112808	0.000186848	0.000394182	-0.000375637	0.000540307
_	1002	H-2	0.03547722	0.039111703	0.032864011	0.018601666	0.048988675	0.037060221	0.025207034	0.030567043	0.03551103	0.029176764	0.037970908	0.030991795	0.033814517
_	1003	H-3	2.09434E-05	-1.7701E-05	9.39538E-05	-3.2355E-05	5.68867E-05	1.00677E-05	1.94231E-05	-7.04671E-06	1.82404E-05	Identical	3.21384E-06	Identical	2.98309E-06
_	2003	He-3	Not Available	Not Available	Not Available	Not Available	Not Available	0.001968784	0.001801894	Not Available	0.001/18885	Not Available	0.001426892	0.001533082	0.001669799
-	3006	Li-6	Not Available	Not Available	Not Available	Not Available	Not Available	0.000327636	0.000328343	Not Available	0.000342789	Not Available	0.000387335	0.000402149	0.000792378
	4009	LI-7 Ro-9	-7.080202-00	0.337182-03	9.457765-00	0.002724952	0.000793521	-9.33082-06	1.425255-05	0.000919165	0.002959720	0.000721212	4.502492-05	0.0011444462	-0.008515467
	5010	Be-9	Not Available	Not Available	Not Available	Not Available	Not Available	-1./0030E-03	0.003361677	Not Available	0.002656759	Not Available	0.0005030038	.0.002081038	-9 142995-05
	5010	B-10 B-11	-0.000292379	-0.000225422	0.000463253	-2 27126E.05	9 19/935-06	-0.000114033	-0.000559416	0.000319015	-0.000708007	.7 39776.05	0.000337037	-0.000330132	1.91647E-05
	6012	C-12	0.008433724	0.007313056	0.005699427	0.004464129	0.004663368	0.004061473	0.004614031	0.005106228	0.003896254	0.003417881	0.003663339	0.003775828	0.004081135
	6013	C-12	0.421709453	0.251551921	-0.185447727	-0.191863271	-0.199437094	-0.20002315	-0.209865084	-0.21431554	-0.218446501	-0.225635386	-0.231314783	-0.236897382	-0.245957765
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	7015	N-15	Not Available	Not Available	Not Available	Not Available	Not Available	Identical	Identical	Not Available	Identical	Not Available	Identical	Identical	Identical
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	8016 M101 M901	N-15 O-16 SS316L(N)-IG bivethylene (non-borate	Not Available Not Available -0.066043839 -0.000906151	Not Available Not Available -0.041555803 -0.000181224	Not Available Not Available -0.069184258 0.001025546	Not Available Not Available -0.080374098 0.001275421	Not Available Not Available -0.073125 0.002701598	Identical Identical -0.068473237 0.000237836	Identical Identical -0.067394981 0.000468305	Not Available Not Available -0.066466462 0.00321608	Identical Identical -0.063236719 0.002155598	Not Available Not Available -0.06361713 2.52773E-05	Identical -0.061197676 0.000752448	Identical Identical -0.055023823 0.001911431	Identical Identical -0.054477566 0.002199026
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	7015 8016 M101 M901 M904 M905 M903 M902 M909	N-15 O-16 SS316L(N)-IG Divethylene (non-borate Resistive_magnet mat_Thermal_Shield mat_PF_coil_casing at_TF_coil_inb inb_tf_ta mat_Shield_inboard_3	Not Available Not Available -0.066043839 -0.00906151 0.019907667 -0.142739711 -0.142739711 -0.00983393 0.040038937	Not Available Not Available -0.041555803 -0.000181224 -0.062302974 -0.062302974 -0.00800827 0.00080827	Not Available Not Available 0.069184258 0.01025546 0.01865274 -0.042658563 0.002239686 0.002239686	Not Available Not Available 0.080374098 0.001275421 0.01109531 -0.042135648 0.001016973 0.019451192	Not Available Not Available 0.002701598 0.001834153 0.045576739 0.00190137 0.00190137	Identical Identical 0.068473237 0.000237836 0.012453345 -0.04737036 0.001635419 0.001635419	Identical Identical 0.067394981 0.000468305 0.007935881 -0.059829669 -0.059829669 0.007243558 0.008671636	Not Available Not Available 0.066466462 0.00321608 -0.062137262 -0.062137262 0.01295114 0.01350653	Identical Identical 0.063236719 0.002155598 0.010346922 -0.064061195 -0.064061195 0.003639734 0.010000884	Not Available Not Available -0.06361713 2.52773E-05 -0.066513444 -0.066513444 -0.011136934 -0.005481736	Identical Identical 0.061197676 0.000752448 0.011911765 -0.062924859 0.062924859 0.01050927 0.020354941	Identical Identical 0.055023823 0.001911431 0.018720645 -0.057211791 -0.057211791 -0.003070894 0.009537481	Identical Identical 0.054477566 0.002199026 0.013267567 -0.053017991 -0.053017991 0.012257824 0.009136451
	7015 8016 M101 M901 M904 M905 M903 M902 M909 M200	N-15 O-16 SS316L(N)-IG plyethylene (non-borate Resistive_magnet mat_Thermal_Shield mat_PF_coil_casing at_TF_coil_inb inb_tf_taj mat_Shield_inboard_3 Ordinary Concrete	Not Available Not Available -0.066043839 -0.000906151 -0.142739711 -0.142739711 -0.000983393 0.040038937 0.043804384	Not Available Not Available -0.041555803 -0.000181224 0.010214111 -0.062302974 0.000800827 0.010281627 0.011108788	Not Available Not Available -0.069184258 0.001025546 -0.042658563 -0.042658563 0.002239886 0.012732987 -0.00240026	Not Available Not Available -0.080374098 0.001275421 -0.042135648 -0.042135648 0.001016973 0.019451192 -0.0368184	Not Available Not Available 0.003201598 0.011834153 0.045576739 0.00190137 0.031280321 0.003050864	Identical dentical -0.068473237 0.000237836 0.012453345 -0.04737036 0.001635419 0.019863738 9.24682E-05	Identical Identical -0.067394981 0.000468305 0.007935881 -0.059829669 -0.059829669 0.007243558 0.008671636 -0.002325551	Not Available Not Available -0.066466462 0.00321608 0.006267674 -0.062137262 -0.062137262 0.01350653 -0.006502414	Identical Identical -0.063236719 0.00215558 0.010346922 -0.064061195 0.003639734 0.010000884 -0.00474687	Not Available Not Available -0.06361713 2.52773E-05 -0.066513444 -0.066513444 -0.011136934 -0.005481736 -0.003688773	Identical	Identical Identical -0.055023823 0.001911431 0.018720645 -0.057211791 -0.0370894 0.009537481 -0.007727929	Identical Identical 0.054477566 0.002199026 0.013267567 0.053017991 0.012257824 0.009136451 -0.003920163
	7015 8016 M101 M901 M904 M905 M903 M903 M909 M200 M906	N-15 O-16 SS316L(N)-IG blyethylene (non-borate Resistive_magnet mat_Thermal_Shield mat_PF_coil_casing at_TF_Coil_inb inb_ff_taj mat_Shield_inboard_3 Ordinary.Concrete mat_VV vv_steel	Not Available -0.066043839 -0.000906151 0.019907667 -0.142739711 -0.142739711 -0.000983393 0.04003834 -0.004192636	Not Available Not Available -0.041555803 -0.000181224 0.010214111 -0.062302974 -0.062302974 0.000800827 0.010281627 0.01108788 -0.004309583	Not Available Not Available 0.069184258 0.01025546 0.01865274 0.042658563 0.002239686 0.012732987 -0.00240026 -0.004364616	Not Available Not Available 0.080374098 0.001275421 0.01109531 0.042135648 0.001016973 0.019451192 -0.00368184 -0.001362998	Not Available Not Available 0.073125 0.002701598 0.011834153 0.045576739 0.0045576739 0.00190137 0.031280321 0.03050864 0.0000608059	Identical Identical -0.068473237 0.000237836 0.012453345 -0.04737036 -0.04737036 0.001635419 0.019863738 9.24682E05 -0.004393215	Identical Identical 0.0067394981 0.000468305 0.007935881 0.059829669 0.0059829669 0.007243558 0.008671666 0.002325551 -0.000757066	Not Available Not Available -0.066466462 0.00021608 -0.062137262 -0.062137262 0.010295114 0.01350653 -0.006602414 0.001250784	Identical -0.063236719 0.002155598 0.010346922 -0.064061195 -0.064061195 0.003639734 0.01000084 -0.00474687 -0.0047010782	Not Available Not Available 2.52773E-05 0.0098175 -0.066513444 -0.066513444 0.011136934 -0.005481773 0.003688773 0.003665748	Identical Identical -0.061197676 0.000752448 0.011911765 -0.062924859 -0.062924859 0.01050927 0.020354941 -0.0029268 -0.003318341	Identical Identical 0.055023823 0.001911431 0.018720645 0.057211791 0.057211791 0.003070894 0.009537481 0.009537481	Identical Identical 0.054477566 0.002199026 0.013267567 0.053017991 0.012257824 0.009136451 -0.00920163 0.0006155134
	7015 8016 M101 M901 M905 M905 M903 M902 M909 M200 M906 M907	N-15 O-16 SS3161(N)-IG Resistive_magnet mat_Thermal_Shield mat_PF_coil_casing t_TF_coil_inb inb_tf_ta mat_Shield_inboard_3 Ordinary Concrete mat_VV w_steel mat_Shield_inboard_1	Not Available 0.066043839 0.00906151 0.142739711 0.142739711 0.00983393 0.040038937 0.04038937 0.04038937 0.043804384 0.04192636 0.022866286	Not Available Not Available -0.041555803 -0.000181224 -0.062302974 -0.062302974 -0.062302974 -0.00800827 -0.010281627 -0.01108788 -0.004309583 -0.013741349	Not Available Not Available 0.001025546 0.01025546 0.042658563 0.042658563 0.002239666 0.012732987 -0.00240026 0.00420626 0.012732987 -0.004064616 0.019084322	Not Available Not Available -0.080374098 0.001275421 0.011275421 -0.042135648 -0.042135648 -0.042135648 -0.00136578 -0.0013651192 -0.00368184 -0.001362998 -3.12301605	Not Available Not Available 0.002701598 0.0012701598 0.001834153 0.0045576739 0.0045576739 0.00190137 0.00190137 0.00190137 0.00305084 0.000608059 0.011505928	Identical .dentical 0.0068473237 0.000237836 0.012453345 -0.04737036 0.0014737036 0.00135419 0.019863738 9.24682605 -0.00439215 0.010972879	Identical Identical 0.0067394981 0.00468305 0.059829669 0.059829669 0.007243558 0.008671636 0.002325551 0.0008757066 0.021710655	Not Available Not Available - 0.066466462 0.00321608 0.0062137262 - 0.062137262 - 0.0123514 0.01350653 - 0.006602414 0.001250784 0.013581293	Identical .dentical 0.002155588 0.010345922 -0.064061195 -0.003639734 0.01000884 -0.00476687 -0.00476687 -0.00407682 -0.003875144	Not Available Not Available -0.06361713 2.52773E.00 -0.006513444 -0.065513444 -0.06513444 -0.00513444 -0.005481736 -0.003688773 -0.00368778 -0.005446633	Identical .dentical 0.000752448 0.01911765 -0.062924859 0.0160927 0.020354941 -0.0029268 -0.00318341 0.018346051	Identical Identical 0.0055023823 0.001911431 0.018720645 0.057211791 0.00370834 0.009537481 0.007727929 0.001769325 0.020964006	Identical Identical 0.02199026 0.03267567 0.053017991 0.053017991 0.012257824 0.009136451 0.0091365134 0.006155134 0.00332057
	7015 8016 M101 M901 M904 M905 M903 M902 M909 M200 M906 M907 M911	N-15 O-16 S3316L(N)-16 Resistive_magnet mat_PF_coil_casing st_TF_coil_nbinb_ff_taj mat_Shield_inboard_3 Ordinary Concrete mat_Shield_inboard_1 [HW_W80_ET_h2o13	Not Available 0.06604383 -0.060906151 0.019907667 -0.142739711 -0.142739711 -0.000983393 0.040038937 0.043804384 -0.004192636 0.022866286 -0.02433174	Not Available Not Available -0.041555803 -0.00181224 -0.062302974 -0.062302974 -0.00281627 -0.010281627 -0.01108788 -0.004309583 -0.004309583 -0.00416192	Not Available Not Available 0.069184258 0.00102554 0.042658563 0.002239686 0.012732987 -0.00240026 0.004364522 0.039804322 0.039804322	Not Available Not Available 0.080374098 0.001275421 0.01105531 0.042335648 0.042335648 0.001016973 0.0194551192 0.00368184 0.001362988 -3.12301E05 0.002722465	Not Available Not Available 0.002701598 0.002701598 0.011834153 0.0045576739 0.00190137 0.031280321 0.00150864 0.000608055 0.011506928 0.031367763	Identical Identical 0.068473237 0.000237836 0.012453345 -0.04737036 0.001635419 0.019863738 9.24682E05 -0.004393215 0.010972879 -0.037938785	Identical Identical 0.0067394981 0.007935881 0.0559829669 0.0057823669 0.00871636 0.00871636 0.00871636 0.002720555 0.000757066 0.02171655 0.013510725	Not Available Not Available -0.066466462 0.00321608 -0.062137262 -0.062137262 -0.01237262 -0.01255114 -0.01350653 -0.006602414 -0.0135081293 -0.18437E05	Identical Identical 0.002355588 0.010346922 0.064061195 0.003639734 0.01000884 -0.00474687 -0.00470782 -0.00375144 -0.003433815	Not Available Not Available -0.0636/173 -0.06513444 -0.066513444 -0.00543175 -0.005483773 -0.003685773 -0.003685773 -0.003605748 -0.0054815588	Identical Identical 0.061197676 0.000752448 0.011911765 0.062924859 0.01050927 0.020354941 0.0029268 0.003318341 0.013346051 0.052303217	Identical Identical 0.055022823 0.001911431 0.057211791 0.057211791 0.0057211791 0.003070894 0.009537461 0.000753225 0.0020964006 0.012111482	Identical Identical 0.054477566 0.002199026 0.013267567 0.053017991 0.053017991 0.012257824 0.009136451 0.003320163 0.006155134 0.003320579 0.018988091
	7015 8016 M101 M901 M904 M905 M903 M903 M909 M200 M906 M907 M911 M400	N-15 O-16 S3316L(N)-IG Resistive_magnet mat_Pf_coil_casing at_Tf_coil_inbinb_tf_taj mat_Shield_inboard_3 Ordinary Concrete mat_VV w_steel mat_Shield_inboard_1 IFW_W80_E7_h2o13 Water	Not Available -0.066043839 -0.000906151 -0.142739711 -0.142739711 -0.00983333 0.0403894384 -0.004192636 0.022866286 -0.022866286 -0.02243174 -0.004170168	Not Available Not Available -0.041555803 -0.00181224 -0.062302974 -0.062302974 -0.06080827 0.010281627 -0.01108788 -0.004309583 -0.00430958 -0.00456	Not Available Not Available -0.069184258 0.01025546 0.01855274 -0.042658563 -0.042658563 0.002732986 0.012732987 -0.004364616 0.019084322 0.039804976 -0.002714601	Not Available Not Available -0.080374098 0.001275421 0.011275421 0.042135648 -0.042135648 -0.042135648 -0.042135648 -0.001362998 -3.12201E00 -0.002722465 -0.000935588	Not Available Not Available 0.002701598 0.0012701598 0.001834153 0.0045576739 0.00190137 0.0031280321 0.003050864 0.000508059 0.011500928 0.031367763 0.003528757	Identical Jedentical 0.0068473237 0.000237886 0.012453345 -0.04737036 0.001635419 0.019863738 9.24682605 -0.004393215 0.010972879 -0.037938785 -0.001375134	Identical Identical .0.00468305 .0.07935881 .0.059829669 .0.059829669 .0.059829669 .0.00243558 .0.008671636 .0.002325551 .0.002757066 .0.021710655 .0.013510725 .0.002128894	Not Available Not Available -0.066466462 0.00321608 0.006247674 -0.062137262 0.010255114 0.01350551 -0.006602414 0.001350784 0.001350784 0.001358129 -9.18437605 -0.001028843	Identical Identical 0.002155598 0.0102155598 0.010346922 0.064061195 0.003639734 0.010000844 0.01000084 0.004010782 0.003875144 0.00347518 0.0034558	Not Available Not Available -0.06361713 2.52773E-00 -0.066513444 -0.066513444 -0.00548173 -0.003683773 -0.003608774 -0.003605748 -0.0036548473 -0.0036548473 -0.0036548473 -0.0036548473 -0.00245647	Identical Identical 0.000752448 0.01191765 0.062924859 0.0105927 0.020354941 -0.0029268 -0.003318341 0.018346051 0.05230217 -0.001252266	Identical Identical 0.055023823 0.001911431 0.018720645 0.057211791 0.00370894 0.009537481 0.009537481 0.00759325 0.020964006 0.01211482 0.003223166	Identical Identical 0.002199026 0.013267567 0.053017991 0.01257824 0.009136451 0.000136451 0.000135434 0.003320579 0.018888091 0.00181858
	7015 8016 M101 M901 M905 M903 M909 M200 M909 M200 M906 M907 M911 M911 M910 M900 M203	N-15 O-16 S53161(N)-16 Jyethylene (non-borate Resistive_magnet mat_PF_coli_and mat_Shield_inboard_3 Ordinary Concrete mat_Shield_inboard_3 Ordinary Concrete mat_Shield_inboard_1 IFW_W80_E7_h2013 Water Boron Carbide	Not Available 0.06604383 -0.0609306151 0.019907667 -0.142739711 -0.102739711 -0.00983393 0.040038937 0.043804384 -0.0443804384 -0.0443804384 -0.0443804384 -0.0443804384 -0.0443804384 -0.043804384 -0.02433174 -0.02433174 -0.1376399 -0.1376399	Not Available Not Available -0.041555803 -0.000181224 -0.062302974 -0.062302974 -0.062302974 -0.00800827 -0.01108788 -0.004309593 -0.004309593 -0.004309197 -0.311432409	Not Available Not Available -0.069184258 0.001025546 0.01865274 -0.042658563 0.002239666 0.002239666 0.00243026 -0.00340026 -0.003464616 0.01904322 0.039804976 -0.002714601 Reference = 0	Not Available Not Available -0.080374098 -0.001275421 -0.042135648 -0.042135648 -0.001016973 -0.00368184 -0.00368184 -0.00368184 -0.00368184 -0.003628 -0.002722465 -0.002725465 -0.000275588 -0.001016922	Not Available 0.0073125 0.002701598 0.011834153 0.0045576739 0.0031280321 0.0031280321 0.003050864 0.0000608059 0.01367763 0.0031367763 0.031367765 0.031367765 0.031367765 0.031367765 0.031367765 0.031367765 0.03157777765 0.0315777777777777777777777777777777777777	Identical Identical 0.068473237 0.000237836 0.012453345 -0.04737036 0.011853419 0.01863738 9.24682605 -0.004393215 0.010972879 -0.037938785 -0.001375134 -5.73547E66	Identical Identical 0.00739491 0.000468305 0.007935881 0.059829669 0.008671636 0.00232551 0.00232551 0.00232555 0.0013510725 0.013510725 0.003601414	Not Available 0.066466462 0.00321608 0.006267674 0.062137262 0.062137262 0.062137262 0.001235763 0.010295114 0.01350653 0.006602414 0.001520784 0.013581293 9.18437E05 -0.001028843 0.023401764	Identical 0.063236719 0.00215558 0.010346922 0.064061195 0.064061195 0.003639734 0.0003639734 0.000410782 0.00375144 0.003375144 0.00337514	Not Available Not Available -0.06361713 -0.0698175 -0.066513444 -0.006513444 -0.005481736 -0.003688773 -0.003608774 -0.003688773 -0.003605748 -0.005513588 -0.002458647 -0.137489275	Identical Identical 0.061197676 0.000752448 0.011911765 0.062924859 0.01050927 0.020354941 0.003318341 0.00331834051 0.052203217 0.022303217 0.022303217	Identical Identical 0.05502823 0.001911431 0.018720645 0.057211791 0.057211791 0.009537481 0.009537481 0.00772729 0.000726325 0.022964006 0.012111482 0.003223166 0.337024516	Identical Identical 0.054477566 0.002199026 0.013267567 -0.053017991 0.012257824 0.0091205451 -0.003920163 0.006155134 0.00320579 0.018988091 -0.00155216
	7015 8016 M101 M901 M904 M905 M909 M909 M900 M906 M907 M911 M400 M900 M900	N-15 O-16 S3316L(N)-16 Resistive_magnet mat_PF_coil_casing pt_TF_coil_inb inb_tf_ta mat_Shield_inboard_3 Ordinary Concrete mat_Shield_inboard_1 IFW_W80_ET_h2o13 Water Boron Carbide Natural Silicon	Not Available 0.06604383 -0.060906151 0.019907667 -0.142739711 -0.142739711 -0.000983393 0.040038937 0.043804384 -0.004192636 0.022866286 -0.0243174 -0.004170168 -0.0243174 -0.004170168 -0.175399 Not Available	Not Available Not Available -0.041555803 -0.00181224 -0.062302974 -0.062302974 -0.002816277 -0.01108788 -0.004309583 -0.004309583 -0.00416192 -0.00834117 -0.031432409 Identical	Not Available -0.069184254 0.00102554 0.0185274 -0.042658563 -0.042658563 0.012732987 -0.00240026 -0.004364616 0.019084322 0.039804976 -0.0027146010 Reference -0 3.18947E06	Not Available Not Available 0.080374092 0.001275421 0.01105531 0.042335648 0.002135648 0.001016973 0.019451192 0.0036184 0.001362989 3.12301E05 0.0002722465 0.000335588 0.001016922 3.3842E06	Not Available 0.0021058 0.002701598 0.0012701598 0.001384153 0.0045576739 0.00190137 0.031280321 0.0013050864 0.000608055 0.0013060588 0.0013067763 0.003528775 0.079009471 7.91039E06	Identical Jentical 0.068473237 0.000237836 0.012453345 -0.04737036 0.001635419 0.019863738 9.24622E05 -0.004393215 0.010972879 -0.037938785 -0.001375134 -5.73547E06 6.5392E06	Identical Identical 0.00468305 0.00793581 0.059829669 0.00871636 0.00225551 0.00871636 0.002757065 0.013510725 0.013510725 0.0031144 4.23409E06	Not Available Not Available -0.066466462 0.00321608 0.0062137262 -0.062137262 -0.01237562 -0.012595114 0.01350653 -0.00602414 0.0135081293 -9.18437E05 -0.001028843 -0.023401764 4.20495E06	Identical Identical 0.003236719 0.00215558 0.010346922 0.064061195 0.003639734 0.010000844 0.000474687 0.004010782 0.00343815 0.003343815 0.003343514 0.003343514	Not Available Not Available -0.06361713 -0.06513144 -0.066513444 -0.066513444 -0.00548173 -0.00368773 -0.00368773 -0.00368774 -0.00548173 -0.00368774 -0.005486373 -0.002458647 -0.015313588 -0.002458647 -0.10245864 -0.015313588 -0.002458647 -0.1024887 -0.10245847 -0.1024887 -0.102487 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.102487 -0.1024887 -0.102487 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.1024887 -0.102487 -0.1024887 -0.1024887 -0.1024887 -0.102487 -0	Identical Identical 0.001197676 0.000752448 0.011911765 0.062924859 0.01050927 0.020354941 0.0023268 0.003318341 0.018346051 0.052303217 0.001252296 0.2686655 3.93767E06	Identical Identical 0.055028823 0.001911431 0.018720645 0.057211791 0.0057211791 0.003070894 0.009537481 0.0007537451 0.020964006 0.012111482 0.03223166 0.337024516 3.04532E06	Identical Identical 0.054477566 0.002199026 0.013267567 0.053017991 0.053017991 0.012257824 0.009136451 0.009320163 0.006155134 0.006155134 0.003320579 0.018988091 0.001818855 0.000715216 4.8453E05
	7015 8016 M101 M901 M905 M903 M909 M200 M909 M200 M906 M907 M911 M400 M203 M900 M908	N-15 O-16 S3316L(N)-IG Resistive_magnet mat_Pf_coil_casing at_Tf_coil_casing at_Tf_coil_inbinb_tf_taj mat_Shield_inboard_3 Ordinary Concrete mat_VV w_steel mat_Shield_inboard_2 Natural Silicon mat_Shield_inboard_2	Not Available Not Available -0.066043839 -0.00906151 -0.142739711 -0.142739711 -0.000983393 0.04038933 0.04038934 -0.0041392655 0.022662265 -0.022662265 -0.022662265 -0.0243174 -0.004170168 -0.1376399 Not Available -0.010139347	Not Available -0.041555803 -0.00181224 -0.00214111 -0.062302974 -0.062302974 -0.00800827 0.010281627 0.01108788 -0.004309583 0.013741349 -0.004309583 -0.003834117 -0.311432409 Identical -0.007005009	Not Available 0.069184258 0.001025546 0.01855274 0.042658563 0.042658563 0.002732986 0.012732987 0.00239686 0.019084322 0.039804976 0.002714601 Reference = 0 3.18947E06 -0.002201916	Not Available 0.080374098 0.001275421 0.011275421 0.01275421 0.042135648 0.001275421 0.042135648 0.001362998 -3.12301E00 -0.001362998 -3.12301E00 -0.002722465 -0.00035588 0.001015922 -3.3842E06 0.001576067	Not Available Not Available 0.002701598 0.0012814153 0.0045576739 0.00190137 0.00190137 0.001280321 0.00308064 0.00050864 0.0031280321 0.031367763 0.03292757 0.03297577 0.0329757757 0.0329757757 0.03297577577577577577577757777777777777777	Identical Identical 0.0068473237 0.000237886 0.012453345 -0.04737036 0.001635419 0.013863738 9.24682605 -0.004393215 0.010972879 -0.037938785 -0.001375134 -5.73547E06 -6.5032606 -0.001998208	Identical Identical .0.00468305 .0.07935881 .0.059829669 .0.059829669 .0.059829669 .0.00243558 .0.008671636 .0.002325551 .0.003757066 .0.0212710655 .0.013510725 .0.00350141 .2.09506 .0.001099141	Not Available Not Available - 0.066466462 0.00321608 0.006247674 - 0.062137262 0.010255114 0.01350653 - 0.00602414 0.01350784 0.01358129 - 9.18437E05 - 0.001250784 0.001250784 0.001250784 - 0.0012843 - 0.0012843 - 0.023401764 4.22045E06 0.000526179	Identical Identical 0.002155598 0.0102155598 0.010346922 0.064061195 0.003639734 0.010000844 0.004010782 0.004010782 0.003075144 0.003047687 -0.004010782 0.00304598 0.00304	Not Available 0.06361713 2.52773E05 0.0098175 0.06551344 0.06551344 0.011136934 0.00548173 0.00368773 0.003605748 0.003688773 0.00365748 0.00548647 0.002456647 0.137489275 6.41626506 -0.001796027	Identical Identical 0.0061197676 0.000752448 0.01911765 0.062924859 0.0105927 0.020354941 0.020354941 0.00318341 0.013834601 0.05230217 0.001252296 0.2686655 3.93767E06 -0.003506908	Identical Identical 0.0055023823 0.001911431 0.018720645 0.057211791 0.00370894 0.009537481 0.009537481 0.0075325 0.020964006 0.01211482 0.003223166 0.137024516 3.04532506 -0.007635543	Identical Identical -0.054477566 0.032159026 -0.053017991 -0.053017991 -0.053017991 -0.00312657 -0.00312657 -0.00312657 -0.00312657 -0.00312657 -0.001818585 -0.00715216 -4.843E05 -0.001403528
	7015 8016 M101 M904 M905 M903 M909 M200 M906 M906 M906 M907 M911 M400 M203 M900 M908	N-15 O-16 S3316L(M)+G Resistive_magnet mat_Pf_coil_casing at_Tf_coil_casing at_Tf_coil_inbinb_tf_ta mat_Shield_inboard_12 Ordinary Concrete mat_VV w_steel mat_Shield_inboard_12 Water Boron Carbide Natural Silicon mat_Shield_inboard_2	Not Available Not Available -0.066043839 -0.000906151 -0.142739711 -0.142739711 -0.000983393 0.040038937 -0.004192636 -0.022662266 -0.022662266 -0.022662266 -0.022662266 -0.02433174 -0.004170168 -0.1376399 Not Available -0.010139347	Not Available Not Available -0.041555803 -0.00181224 -0.002202974 -0.002302974 -0.00800827 -0.010281627 -0.01108788 -0.004309583 -0.004309583 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.00416192 -0.004005009	Not Available -0.069184258 0.001025546 0.01865274 -0.042658563 -0.042658563 0.002732987 -0.00436616 0.019084322 0.039804976 -0.002714601 Reference = 0 3.18947E06 -0.002201916	Not Available -0.080374098 0.001275421 0.011275421 0.01275421 0.042135648 -0.042135648 -0.042135648 -0.001016973 0.019451192 -0.001362989 -3.12301E05 -0.00035588 -0.001016922 -0.00035588 -0.001016922 -0.001576067	Not Available Not Available 0.002701598 0.0012814153 0.0045576739 0.00190137 0.0031280321 0.00350864 0.000608059 0.011506928 0.001367763 0.00050864 0.00050865 0.001367763 0.00136976 0.003528757 0.790099471 7.791039506 0.002092215	Identical 	Identical Identical 0.00468305 0.007935881 0.059829669 0.0059829669 0.00743558 0.008671636 0.0021710655 0.01310725 0.002129894 0.002129894 0.003601414 4.23409E06 0.001099141	Not Available Not Available 	Identical Identical 0.002155598 0.0103145922 0.064061195 0.003633734 0.010000844 0.003633734 0.010000844 0.00337314 0.004010782 0.004010782 0.004014588 0.004014588 0.006967725 6.93291E06 -0.009058682	Not Available 0.06361713 2.52773E05 0.0093175 0.06651344 0.011136934 0.005613444 0.001385934 0.003681773 0.003605748 0.003605748 0.003648647 0.0034513588 0.002458647 0.137489275 6.41626E06 -0.001796027	Identical Identical 0.0061197676 0.000752448 0.01191765 0.062924859 0.01050927 0.020354941 0.00318341 0.018346051 0.052303217 -0.001252296 0.2686655 3.93767E06 -0.003506908	Identical Identical 0.0055023823 0.001911431 0.018720645 0.057211791 0.003070894 0.009537481 0.009537481 0.00372929 0.001769325 0.020964006 0.012111482 0.003223166 0.0137024516 3.04532E06 -0.007635543	Identical Identical 0.002199026 0.013267567 0.053017991 0.012257824 0.009136451 0.009136451 0.009136451 0.0033201579 0.01888091 -0.0011818585 -0.00715216 -4.843E-05 -0.001403528
	7015 8016 M101 M904 M905 M903 M909 M909 M200 M909 M909 M900 M911 M400 M907 M911 M400 M907 M913 M900 M908	N-15 O-16 S33161(N)-16 Resistive_magnet mat_Fr_coil_inhon_borta mat_Fr_coil_inhon_brta mat_Shield_inhorad_3 Ordinary Concrete mat_Shield_inhorad_1 IFW_W80_E7_h2o13 Water Boron Carbide Natural Silicon mat_Shield_inhorad_2	Not Available Not Available -0.06604383 -0.00906151 -0.142739711 -0.142739711 -0.00983333 -0.040038937 -0.043804384 -0.043804384 -0.043804384 -0.04438248 -0.04438248 -0.04438248 -0.02433174 -0.0139347 -0.0139347	Not Available Not Available -0.041555803 -0.000181224 -0.062302974 -0.062302974 -0.062302974 -0.00800827 -0.01108788 -0.004305583 -0.004305583 -0.00416192 -0.007005009 4.146e07 [Mex] [141	Not Available 0.069184255 0.00102554 0.01865274 0.042658563 0.002236866 0.012732987 0.00230666 0.012732987 0.00240026 0.0094322 0.039804976 0.002714601 Reference = 0 3.18947E/06 -0.002201916 GLOBAL Q 3.1806271 MeV1 [r/1]	Not Available Not Available 0.080374098 0.001275421 0.01109531 0.042135648 0.042135648 0.001016973 0.019451192 0.00368184 0.001362989 0.31201405 0.002722465 0.0002722465 0.000156922 3.3842E06 0.001015922 3.3842E067 UICK RESULT: %	Not Available 0.073125 0.002701598 0.011834153 0.00190137 0.031280321 0.00190137 0.031280321 0.003050864 0.003050864 0.003050864 0.003050867 0.031367763 0.031367765 0.031367765 0.031367765 0.031367765 0.031367765 0.031367765 0.031577776 0.0315777777777777777777777777777777777777	Identical Identical 0.068473237 0.000237836 0.012453345 -0.04737036 0.01863738 9.24682605 -0.004393215 0.01097879 -0.037938785 -0.001375134 -5.73547E06 6.5392E06 -0.001998208 of comparison c	Identical Identical 0.004739491 0.000468305 0.007935881 0.059829669 0.007243555 0.00871658 0.002720555 0.00272055 0.013510725 0.013510725 0.013510725 0.013510725 0.013510725 0.00301414 4.23409E06 0.0001099141 Iifferences	Not Available Not Available -0.066465462 0.00321608 0.006267674 -0.062137262 -0.062137262 -0.062137262 -0.062137262 -0.010255174 0.01355123 -0.010250784 -0.010250784 -0.01025078 -0.001028843 -0.023403764 -0.000526179	Identical Identical 0.062326719 0.00215558 0.010346922 0.064061195 0.064061195 0.003639734 0.003639734 0.000785144 0.00347514 0.00347514 0.00347514 0.00347514 0.00343815 0.0034588 0.006967725 6.93231E/06 0.009058682 2.382a.06 [Mey1141]	Not Available Not Available -0.06581713 -0.065813144 -0.066513444 -0.005613444 -0.005613444 -0.003683773 -0.003683773 -0.003683773 -0.003685748 -0.005456847 -0.15513588 -0.002458647 -0.15513588 -0.001796027 -0.001796027	Identical Identical 0.061197676 0.000752448 0.011911765 -0.062924859 0.01050927 0.020354941 -0.0023268 -0.003318341 0.0331834051 0.052203217 -0.001252296 0.2686555 3.937676.06 -0.003506908	Identical Identical 0.05502823 0.001911431 0.018720645 0.057211791 0.067211791 0.003070894 0.00037481 0.00777929 0.001769325 0.02064006 0.012111482 0.00323166 0.37024516 3.04532606 -0.007635543 5.0438.065 [MeV] 1:41	Identical Identical 0.054477566 0.002199026 0.013267567 -0.053017991 0.012257824 0.00312016451 -0.0032016431 0.00312016451 0.00312016451 -0.0032016451 -0.0032016451 -0.0032016451 -0.0032016451 -0.001551216 -4.8453E-05 -0.001403528 6.4766.06 [Math] [Math]
	7015 8016 M101 M901 M904 M905 M909 M909 M909 M906 M906 M906 M907 M911 M400 M906 M900 M908	N-15 O-16 S3316L(M)-16 Resistive_magnet mat_PF_coil_casing pt_TF_coil_inb inb_tf_ta mat_Shield_inboard_1 Ordinary Concrete mat_Shield_inboard_1 IFW_W80 ET_h2o13 Water Boron Carbide Natural Silicon mat_Shield_inboard_2 Range Cat% of calls < 5.0	Not Available 0.066043839 -0.000906151 0.019907667 -0.142739711 -0.142739711 -0.000983393 0.040038937 0.043804384 -0.004192636 0.022866286 -0.0243174 -0.004170166 -0.0243174 -0.0043701599 Not Available -0.010139347 1e-07 [MeV] [t4] 0.72727273	Not Available Not Available -0.041555803 -0.00181224 -0.062302974 -0.062302974 -0.00281627 -0.01108788 -0.004205938 -0.00410928 -0.00410928 -0.00410928 -0.00410928 -0.00416192 -0.008384117 -0.00416192 -0.008384117 -0.00416192 -0.003834117 -0.00416192 -0.003834117 -0.00416192 -0.007005009	Not Available -0.069184258 0.00102554 0.0185274 -0.042658563 -0.042658563 0.012732987 -0.00240026 -0.004364616 0.019084322 0.039804976 -0.002714601 Reference -0 3.18947E06 -0.002201916 5.3316e-07 [MeV] [(4)] 0.860565212	Not Available 0.080374098 0.001275421 0.01105531 0.042335648 0.042335648 0.001016973 0.019451192 0.0036184 0.001362989 -3.12301E05 -0.002722465 -0.000335588 -0.001016922 3.3842E06 0.001575067 UICK RESULT: % 6.8256e-07 [MeV] [MeV] 0.913043778	Not Available 0.073125 0.002701598 0.011834153 0.001834153 0.00190137 0.031280321 0.00190137 0.031280321 0.001506928 0.0113050864 0.00050864 0.00050865 0.013367763 0.03035877 0.790099471 7.91039E06 0.002092215 of cells per range 1.764e-97 [MeV] [tel] 0.86955217	Identical Identical 0.068473237 0.000237836 0.012453345 -0.04737036 0.001635419 0.019863738 9.2462205 -0.004393215 0.010972879 -0.037938785 -0.001375134 -5.73547206 -6.5392206 -0.001998208 e of comparison of 1.125e-o6 [MeV] [K4] 0.931034433	Identical Identical 0.0067394981 0.000468305 0.00793581 0.059829669 0.007243558 0.008671636 0.00225551 -0.00757066 0.021710655 0.013510725 -0.002129894 -0.00301414 4.23409E06 0.001099141 Ilifferences 1.445e-06 [MeV] [tel] 1.4658566	Not Available Not Available -0.066466462 0.00321608 -0.062137262 -0.062137262 -0.062137262 -0.012395114 0.01350633 -0.00602414 0.013581293 -0.13581293 -0.13581293 -0.01028843 -0.02301764 4.20495E06 0.000526179	Identical Identical 0.002135598 0.010345922 0.064061195 0.003639734 0.010000844 0.000474687 0.000474687 0.000474687 0.003435154 0.003435154 0.003435154 0.003435154 0.00344595 6.99291E06 0.009058682	Not Available Not Available -0.06361713 2.52773E-05 0.0098175 -0.066513444 -0.066513444 -0.005483773 -0.003605748 -0.003605748 -0.003605748 -0.002458647 -0.137489275 6.41626E-06 -0.001796027 -0.262608596	Identical Identical 0.001197676 0.000752448 0.011911765 -0.062924859 0.01050927 0.020354941 -0.0029268 -0.00318341 0.018346051 0.052303217 -0.001252296 0.2686655 3.93767E06 -0.003506908 3.928e-06 (MeV] [t4] 0.733103488	Identical Identical 0.055028823 0.001911431 0.018720645 0.057211791 0.0057211791 0.003070894 0.009537481 0.000763525 0.020964006 0.012111482 0.003223166 0.037026516 3.04532E06 0.007635543	Identical Identical 0.035477566 0.002199026 0.013267567 0.053017991 0.012257824 0.009136451 0.009320163 0.006155134 0.000320579 0.018988091 0.001818585 -0.00715216 -4.8453E05 -0.001403528
	7015 8016 M101 M904 M905 M903 M909 M200 M200 M306 M306 M307 M306 M307 M300 M300 M300 M300 M300 M300	N-15 O-16 S53161(N)-16 Jyethylene (non-borate Resistive_magnet mat_PF_coil_inbinb_tf_a mat_Shield_inboard_1 Ordinary Concrete mat_Shield_inboard_1 IFW_W80_E7_h2013 Water Boron Carbide Natural Silicon mat_Shield_inboard_2 Range 0 <% of cells < 5.0	Not Available Not Available -0.066043839 -0.00906151 0.019907667 -0.142739711 -0.142739711 -0.00983393 0.04038937 0.043804384 -0.004192656 -0.02433174 -0.004170168 -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 Not Available -0.1376399 -0.1376399 -0.1376399 -0.137639 -0.137639 -0.137639 -0.137639 -0.137639 -0.137639 -0.137639 -0.137639 -0.137639 -0.14765 -0.14765 -0.14765 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.14776 -0.147777 -0.147777 -0.147777 -0.147777 -0.1477777 -0.1477777 -0.1477777777777 -0.1477777777777777777777777 -0.14777777777777777777777777777777777777	Not Available Not Available -0.041555803 -0.00181224 -0.00220274 -0.062302974 -0.00800827 -0.01108788 -0.004309583 -0.004309583 -0.004309583 -0.00416192 -0.004309583 -0.00416192 -0.004100 -0.00410 -0.004100 -0.004100 -0.004100 -0.004100 -0.004100 -0.004100 -0.004100 -0.004100 -0.004100 -0.00410 -0.004100 -0.00410 -0.004100 -0.00410 -0.004000 -0.00400 -0.00400 -0.004000 -0.0040000000 -0.0040000000000	Not Available -0.069184258 0.001025546 0.01865274 -0.042658563 -0.042658563 -0.04239586 0.012732987 -0.00436616 0.019084322 0.039804976 -0.002714601 Reference = 0 3.18947E06 -0.002201916 S.316e-07 [MeV] [t4] 0.889565217 0.08328561	Not Available -0.080374098 0.001275421 0.011275421 0.01275421 0.01275421 0.042135648 -0.042135648 -0.001016973 0.019451192 -0.001362998 -3.12301E-05 -0.00035588 -0.001016922 -0.00035588 -0.001016922 -0.001576067 UICK RESULT: % 6.8256-07 [MeV] [tel] 0.913043478 0.913043478	Not Available Not Available 0.002701598 0.001284153 0.0045576739 0.00190137 0.00350864 0.000608059 0.00130050864 0.000608059 0.011506928 0.0013160763 0.001506928 0.001306765 0.003528757 0.790099471 0.790099471 0.791039E06 0.002092215	Identical Identical 0.0068473237 0.000237886 0.012453345 -0.04737036 0.001635419 0.019863738 9.24682605 -0.004393215 0.010972879 -0.037936785 -0.001375134 -5.73547E06 -6.5392E06 -0.001998208 cof comparison of 1.125e-06 [MeV][14] 0.931034483 0.931034483 0.931034483 0.931034483 0.014482759	Identical Identical .0.00468305 .0.07935881 .0.059829669 .0.059829669 .0.059829669 .0.0073743588 .0.008671636 .0.00212710655 .0.01310725 .0.002129894 .0.00350174 .0.0001099141 Ilifferences 1.445e-06 [MeV] [t4] .0.852068966 .0.103448276	Not Available Not Available 	Identical Identical 0.002325559 0.002155598 0.010345922 0.064061195 0.003639734 0.010000844 0.003639734 0.000010782 0.004010782 0.004010782 0.004010782 0.00304598 0.00005667725 6.99291E06 -0.009058682 2.382e-06 [MeV] [t4] 0.852065956 0.103448276	Not Available 0.06361713 2.52773E05 0.0093175 0.06551344 0.011136934 0.005613444 0.01136934 0.003681773 0.003605748 0.003605748 0.003648647 0.003648647 0.137489275 6.41626E06 -0.001796027 3.059e-06 [MeV] [t4] 0.782608696 0.130434783	Identical Identical 0.061197676 0.000752448 0.01191765 0.062924859 0.01050927 0.020354941 0.00318341 0.0138346051 0.05203217 0.00316348 0.01252296 0.2686655 3.93767206 -0.003506908 3.928e-06 [MeV] [t4] 0.793103448 0.13731034	Identical Identical 0.055023823 0.001911431 0.018720645 0.057211791 0.003070894 0.009537481 0.00372929 0.001769325 0.020964006 0.012111482 0.003223166 0.0137024516 3.04532E06 0.037024516 3.04532E06 0.037024513 5.043e-06 [MeV][t4] 0.827586207 0.103448276	Identical Identical 0.002199026 0.013267567 0.053017991 0.012257824 0.003136451 0.003920163 0.006155134 0.0033201579 0.01888091 0.00315216 0.00315258 0.00715216 0.001403528 6.476e-06 [MeV] [t4] 0.852068966 0.10348476
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UKAEA Future Effort

FENDL validation and importance for future applications



Additional benchmarks in JADE











CIAE Fe, CoNDERC, IAEA



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UK Atomic



Openly available, interoperable benchmark data is fundamental to these efforts

Future work

- UK Atomic Energy Authority
- Currently working towards a release **v3.0.0** of the code in Q1 2024. Complete JADE portability to Linux without feature loss from current version.
- □ Complete functionality for OpenMC and Serpent across all benchmarks.
- Further addition of 1D benchmarks consider parametric builds. Important for STEP and UKAEA Fusion Futures programme.
- □ Addition of FNG Cu.
- □ Variance reduction techniques developed where required.
- JADE GUI
- □ Work with OpenMC and Serpent developers on addressing needs for JADE.



UK Atomic Energy Authority

Thank you for listening

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