

CFETR Neutronics Benchmark Crosschecking Using JMCT

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ABSTRACT

- China Fusion Engineering Test Reactor (CFETR) is under engineering design, tritium self-sufficiency is one of its biggest challenges.
- Joint Mont Carlo neutron-photon-electron Transportation code(JMCT) is used to crosscheck three kinds of blanket concepts of CFETR with the aid of JLAMT(a 3D visual pre-processor) and CMGC (a 3D visual pre-processor and a CAD to Monte Carlo Geometry Converter tool) .
- Tritium Breeding Ratio Calculation results are all in good agreement while some IDEAL ASSUMPTIONS in design models should be invested further.

BACKGROUND

- A fusion reactor with 1 G W nuclear power consumes about 152 g/day tritium and needs at least several kilograms startup tritium inventory.
- To suffice tritium self-sufficiency, the achievable tritium breeding ratio (TBR_{ach}) must be greater than the required tritium breeding ratio(TBR_{req}).
- According to Professor Abdou, the maximum value of TBR_{ach} is about 1.15, while the state of art TBR_{req} may be as high as 1.20.
- Considering the ~10% uncertainties (in nuclear data, detailed 3D modeling, fusion design elements), there must be a range of breeding margins in TBR_{3D} to keep the Net TBR greater than TBR_{req}
- There are 3 kinds of pure fusion blanket design concepts and 2 kinds of fusion fission hybrid concepts as backup for CFETR in stage I(200MW) benchmark. The recommend design in stage II(1000MW) benchmark is HCPB(Helium Cooled Pebber Bed).

CHALLENGES / METHODS / IMPLEMENTATION

COMPLEX 3D GEOMETRY MODELING IS NECESSARY FOR ACCURATE TRITIUM BREEDING RATIO CALCULATION

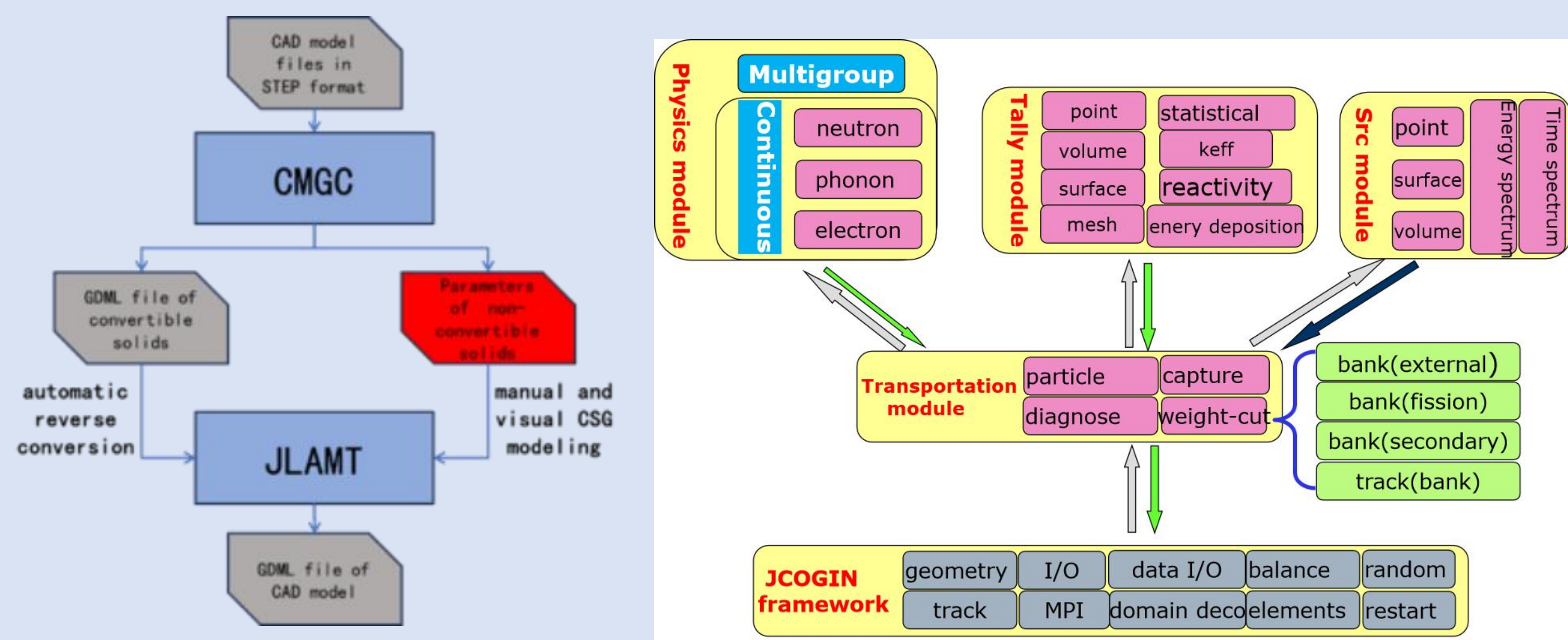
- CFETR benchmark consists of blanket modules, divertor, vacuum chamber, upper port window, equatorial window and other parts. More than 20,000 bodies are used to define CFETR frame work.

COMBINE THE BREP TO CSG CONVERSION CODE CMGC WITH THE VISUAL CSG MODELING CODE JLAMT

- CMGC converts .stp file into a **GDML**(Geometry Description Markup Language) file directly, JLAMT finish incremental modeling for non-convertible solids and outputs the complete GDML file.

JMCT READ THE GDML FILE AND COMPLETE NEUTRONICS CALCULATION

- JMCT1.0 was issued in 2013, JMCT2.0 in 2017, JMCT3.0 in 2022. It is different from MCNP in software infrastructure, geometry description and modeling, parallel computing,etc.



Geometry modeling process

JMCT structure

OUTCOME

THE RELATIVE ERROR OF GLOBAL TBR ARE ALL WITHIN 0.5%

All the JMCT crosschecking results are in good agreement with those of reference values and the relative error of calculated TBR are all within 0.5%.

THE RELATIVE ERROR OF LOCAL TBR ARE SATISFYING

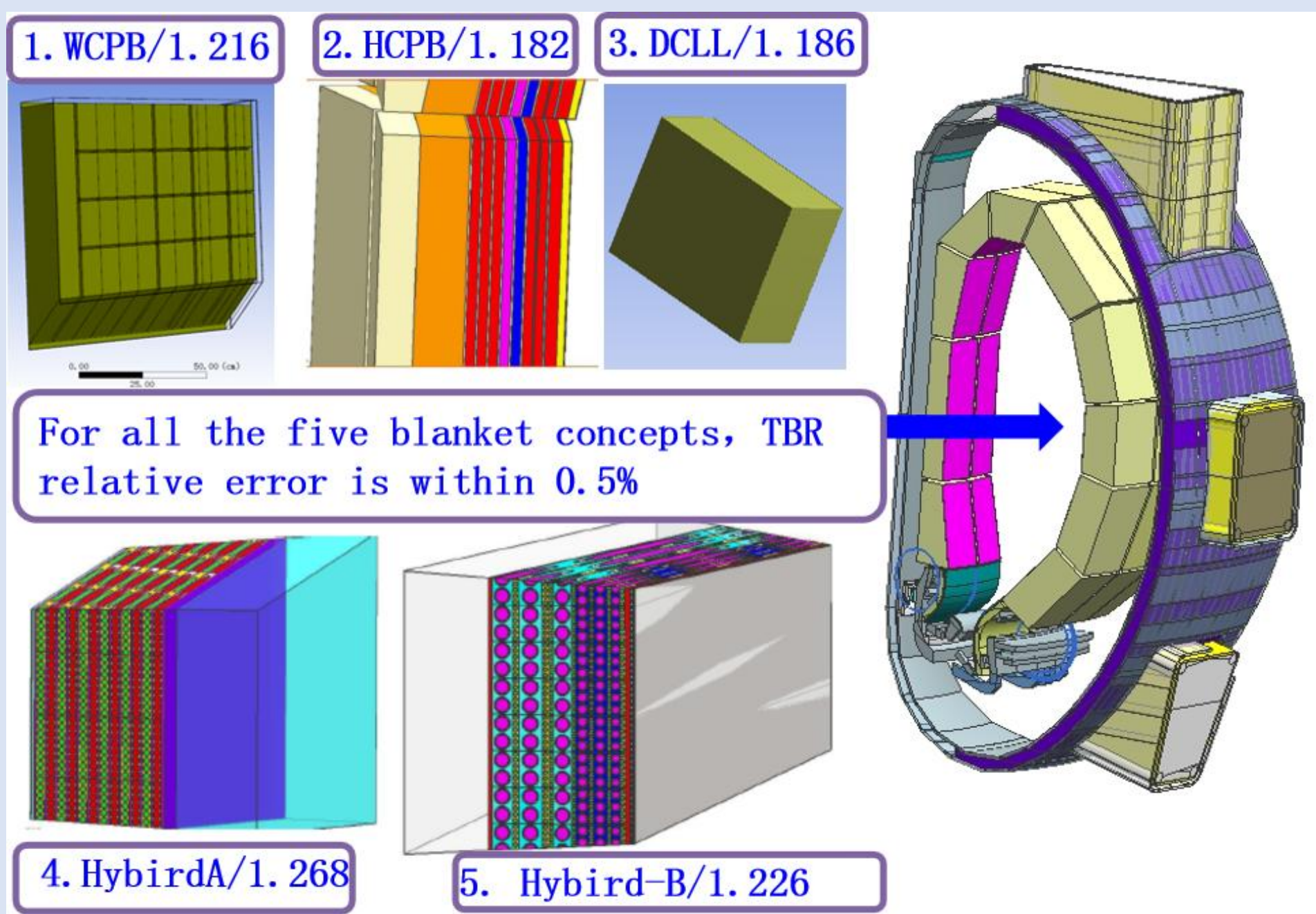
For WCPB model, there are 707 tritium production cells, 546 of them with relative error less than 1%, which contributes 93.96% to TBR. There are 47 cells with relative error bigger than 2%, which contributes 0.47% to TBR.

THE TIME CONSUMING GEOMETRY COVERSION WORK ARE RELIEVED

The 1000MW CFETR benchmark based on up to date CAD files in STP format are converted to JMCT input file within 1255 seconds.

THERE ARE IDEAL ASSUMPTIONS IN ALL THE NEUTRONICS MODELS

Homogenization is widely used , each cell is either a plate or a wedge which is not consistent with the thermal hydraulic models.



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Results of WCPB model

TBR	JMCT(1.216)	MCNP(1.215)
deviation	number of lithium cells	tritium production rate
distribution	(% of total cells)	(% of contribution to TBR)
<1%	546(77.23%)	1.143(93.96%)
1%-2%	114(16.12%)	0.067(5.57%)
>2%	47(6.64%)	6.59E-3(0.47%)

CONCLUSION

- CMGC combine JLAMT can convert CAD files effectively to GDML input files for JMCT, it saves a lot of manual work.
- JMCT shows good agreement in TBR with MCNP ,however, the local deviation may be as high as 2% for a few low tritium contribution cells.
- Simplification or ideal assumptions exit in all the 5 blanket models, it may overestimate TBR and should be further investigated in future

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