



Global Evaluation of The Prompt Dose in ITER using The Hybrid Monte Carlo/Deterministic Techniques

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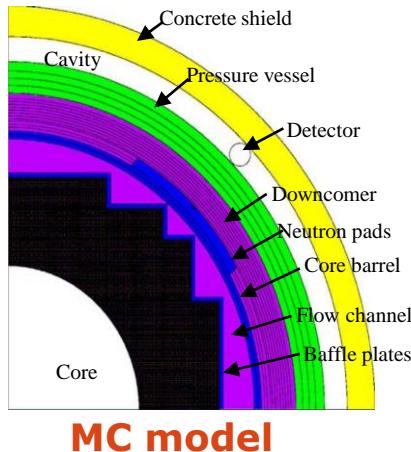


Outline

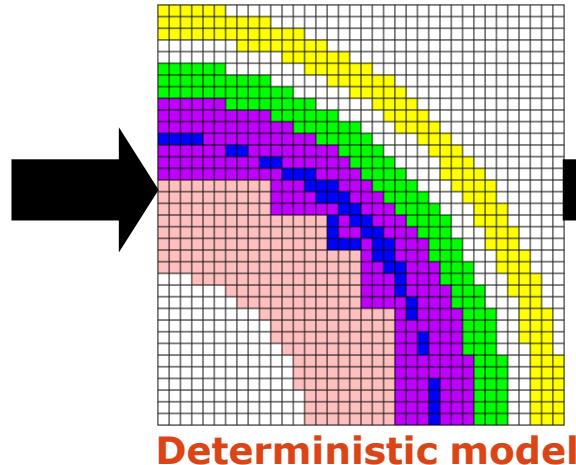
- ADVANTG
- Dose at a point
- Macromaterials (MM) approach
- Adjoint flux collapsing
- Global dose
- Conclusion



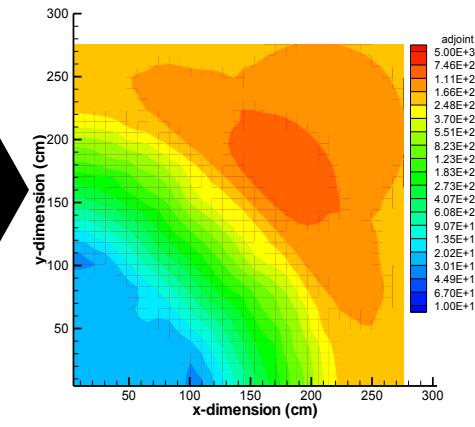
ADVANTG (CADIS, FW-CADIS) dramatically speeds up calculation



MC model



Deterministic model



Adjoint flux

Results

Case	CPU time (hr) for 1% uncertainty	Speed up
No VR	8.86E+4 (10.1 yrs)	1
Manual VR	13.6	6500*
ADVANTG	1.02	87000

* Required ~3 weeks by an experienced MC practitioner using all applicable MCNP4C VR capabilities

MC

CADIS calculation of VR parameters

Source biasing

$$\hat{q}(\bar{r}, E) = \frac{\phi^+(\bar{r}, E) q(\bar{r}, E)}{R}$$

Weight windows

$$w_\ell(\bar{r}, E) = \frac{R}{\phi^+(\bar{r}, E)}$$



ADVANTG is fast and easy

- **Automatic** creation of deterministic input file
- Only approximate deterministic fluxes
 - Coarse mesh

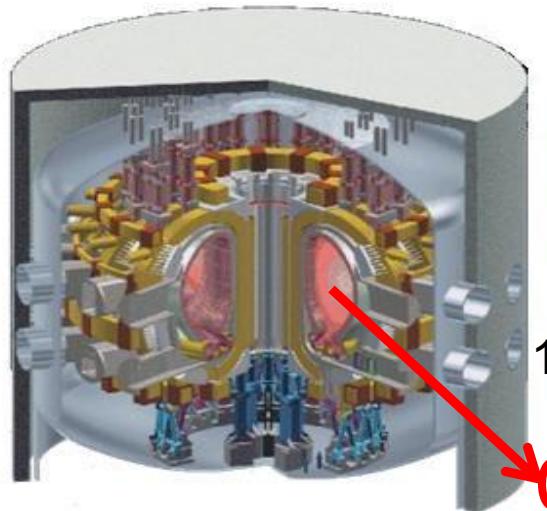
Number of cells and running times of deterministic calculations

		Number of cells (millions)	Forward calculation time (hr)	Adjoint calculation time (hr)
Dose at a point		0.6	-----	1.9
Dose at 4 points		1.2	4.3	2.9
Global dose	Coarse	1	3.8	2.7
	Fine	8	24×3.3=80	24×2.6=62
	MM	1	4	3

Minimal penalty from deterministic part of hybrid sequence



Traditional Monte Carlo cannot calculate dose outside bioshield



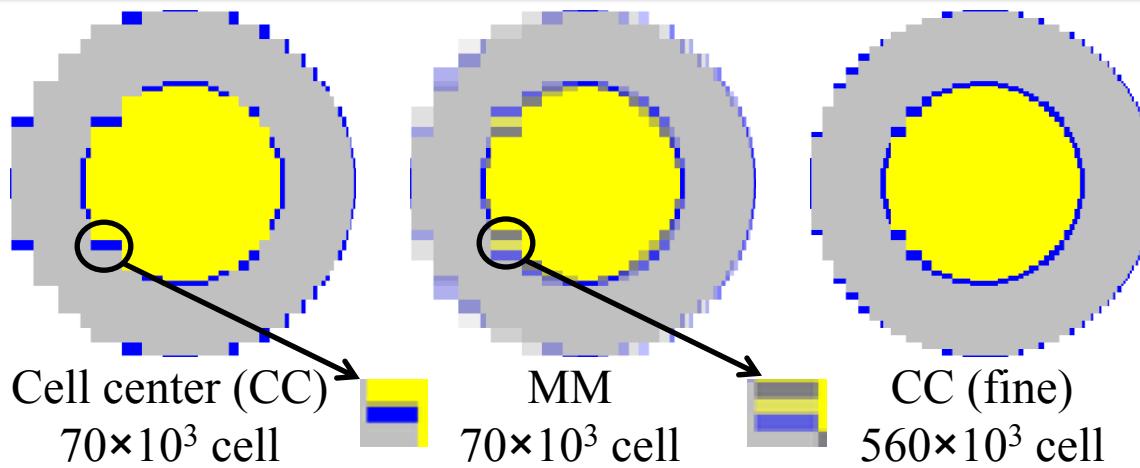
14 orders of magnitude total neutron flux attenuation

	Dose ($\mu\text{Sv/hr}$)	Relative uncertainty (RU)	Time (day)	Speed up
MC(no CADIS)	4.8	76.7%	610.0	1
MC (CADIS)	2.7	3.8%	8.6	29,000

Requires 393 years to reach 5% RU



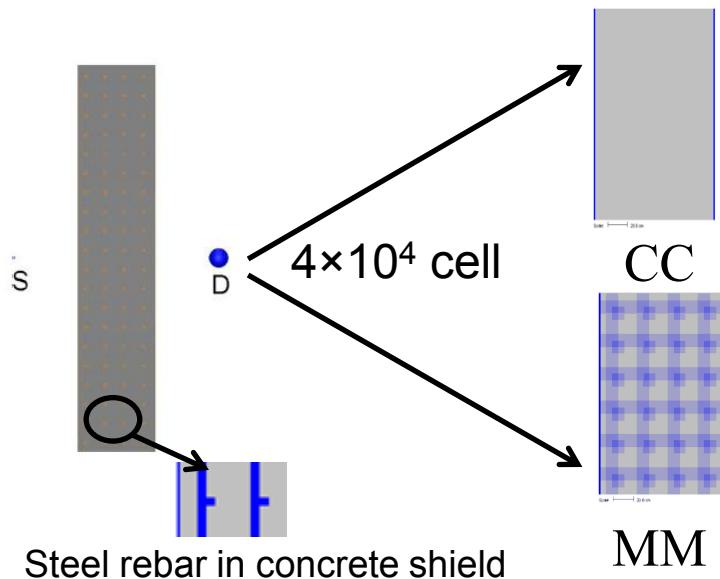
Macromaterials (MM) approach



Deterministic (Denovo)

Calculation	Time (min)	Dose Rate ($\mu\text{Sv}/\text{hr}$)
CC	7.6	7.2
MM	8.3	5.9
CC (fine)	62.5	3.6

MM closer to the right answer without time penalty



Monte Carlo (Monaco)

	Denovo time (min)	Dose ($10^{-11}\text{Sv}/\text{hr}$)/Ci (Monaco)	Speed up
CC	20.9	2.5	1
MM	20.6	2.5	2.1

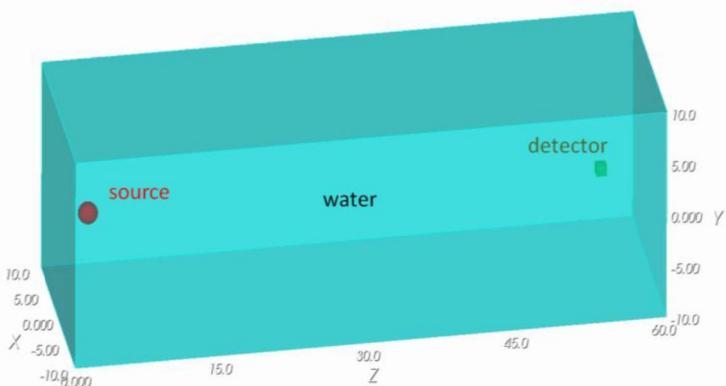
- Better MC FOM (speedup) for free
- Already in SCALE 6.1



Adjoint flux collapsing

$$\phi^+(\bar{R}, E_{coarse}) = \frac{\int_{E_{coarse}} \int_{\bar{R}} \varphi(\bar{r}, E) \phi^+(\bar{r}, E) dVdE}{\int_{E_{coarse}} \int_{\bar{R}} \varphi(\bar{r}, E) dVdE}$$

ϕ^+ : Adjoint flux
 φ : Forward flux density



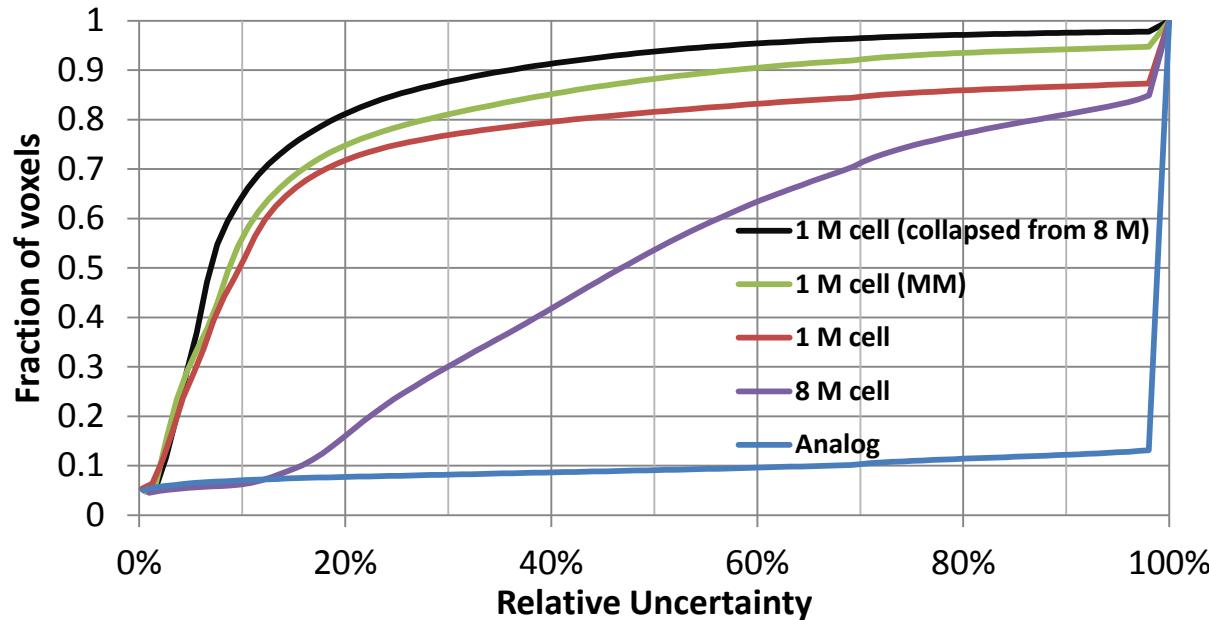
Calculation	Total number of energy mesh cells	Total flux per unit source (n/cm ² -sec)	Speed up (FOM, deterministic correction)
Analog	----	6.62E-08	1
Coarse mesh	10,125	5.27E-08	1,700
Fine mesh	1,265,625	5.27E-08	21,684
Adjoint average	3,000	5.27E-08	10,933
Adjoint weighted average	3,000	5.26E-08	13,180

- Decrease in weight window map size
 - 400
- Decrease in speed up (FOM)
 - <2



MM and adjoint flux collapsing effects on global MC efficiency

Mesh tally cumulative distribution function (CDF) for 10 days MCNP runs

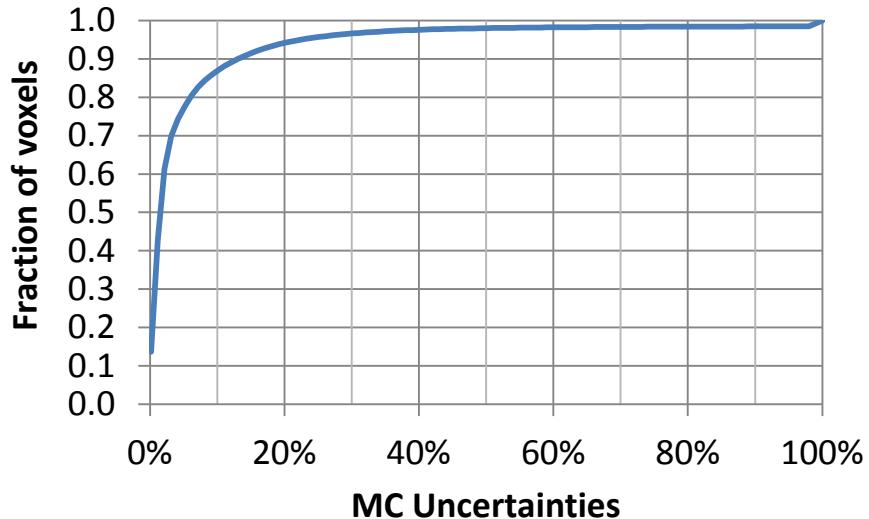


Calculation	Voxels fraction <10% RU	Voxels fraction <100% RU
Analog	7.0%	13.1%
8 Million cell	6.2%	84.9%
1 Million cell	51.1%	87.3%
MM	56.0%	94.7%
Collapse	64.4%	97.8%

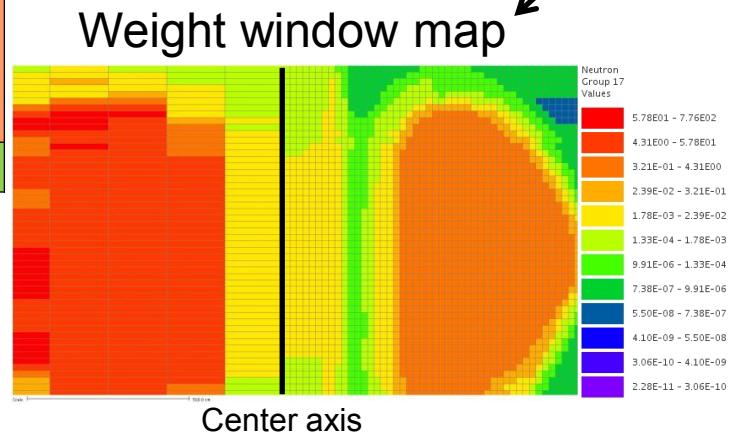


Global prompt dose

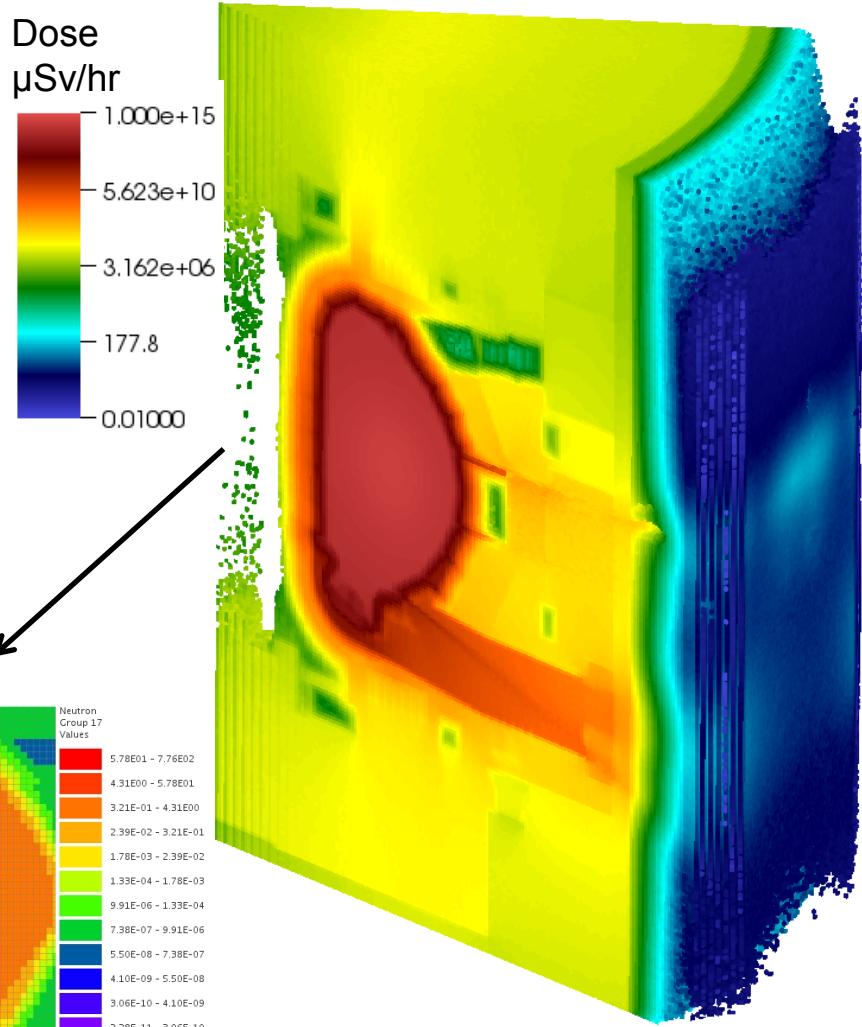
Mesh tally CDF, 120 days MCNP run



Voxels fraction <10% RU	Voxels fraction <100% RU
87.0%	98.5%

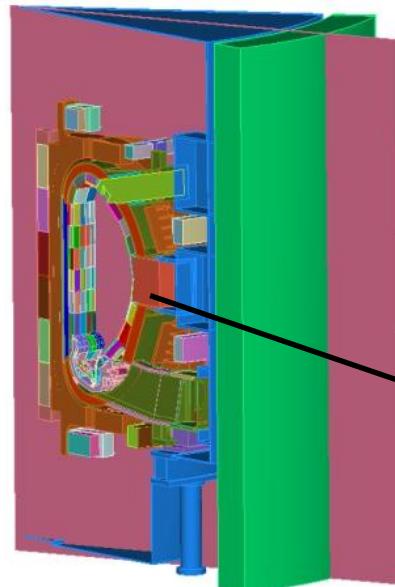


Voxels with < 20% RU



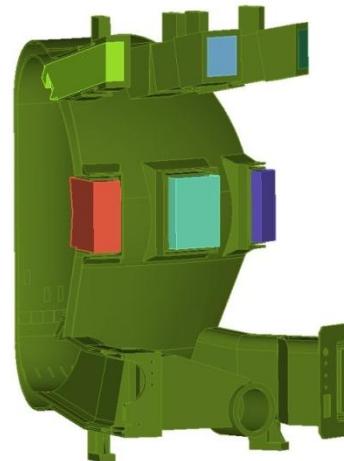


Ports effects

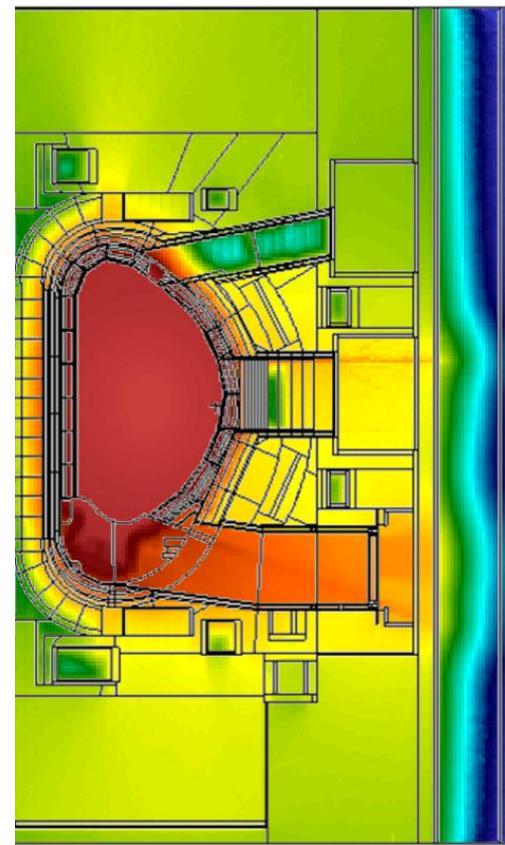


Central
plane

20° plane

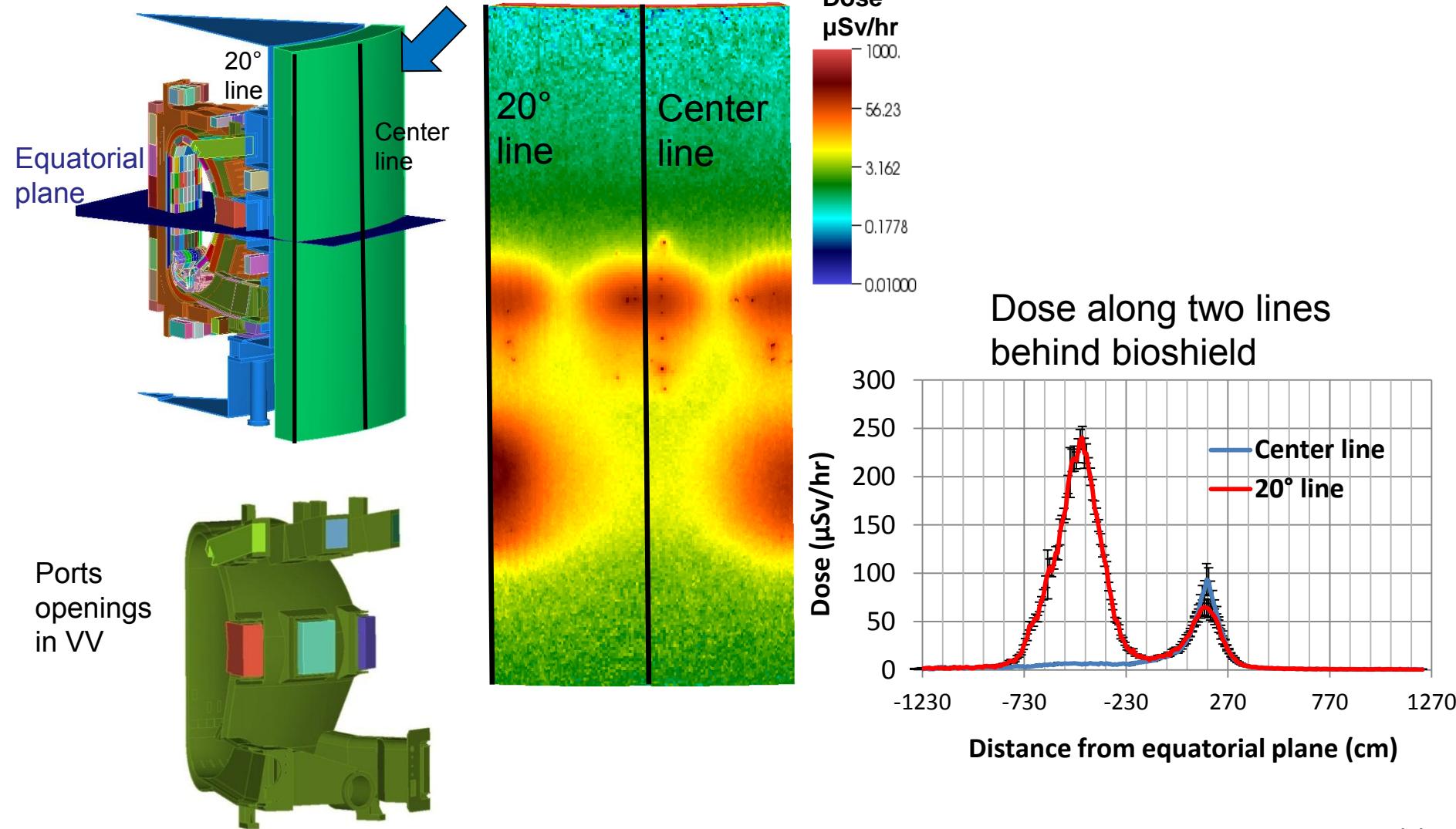


Ports plugs
in VV



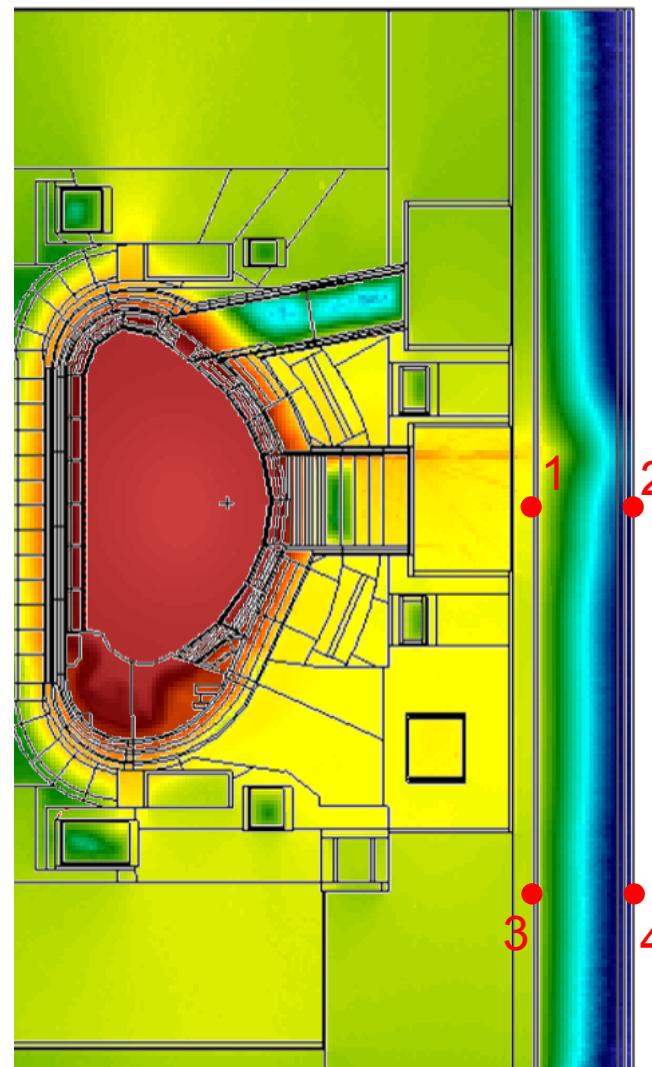


Dose at back surface of bioshield





Accuracy of global calculation

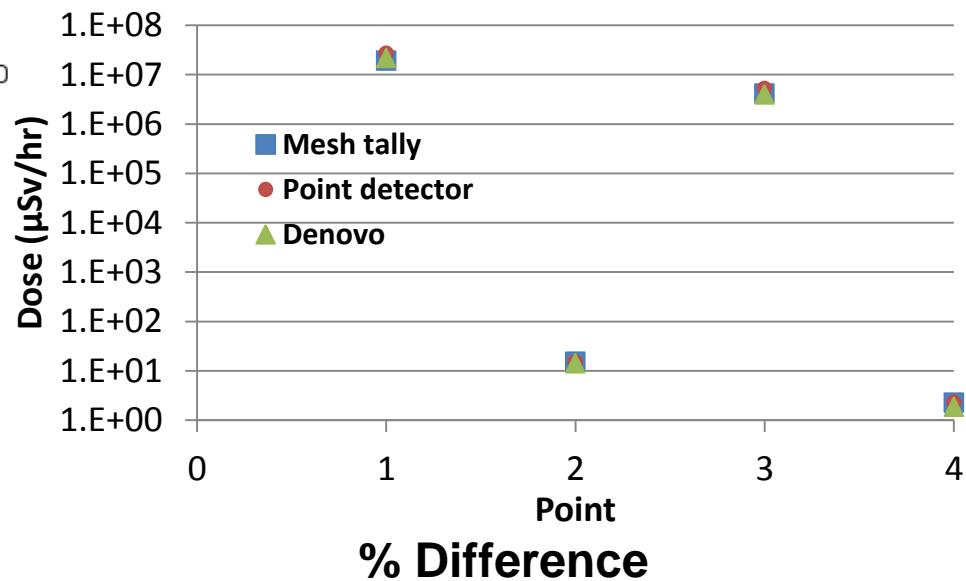


Dose
 $\mu\text{Sv}/\text{hr}$

1.000e+15
1.000e+11
1.000e+07
1000.
0.1000



Cells	1.34×10^9
Groups	67
Cores	4.02×10^4
Time	7.6 hr
Total time	35 years



Mesh tally and Pt. Det.	1%-29%
Mesh tally and Denovo	4%-19%
Pt. Det. and Denovo	5%-25%



Conclusion

With FW-CADIS, full global 3-D MC analysis of large and complicated models such as ITER **is** possible