Comparing MCNPX and PHITS

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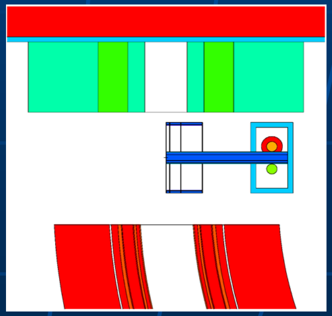
Introduction

- WARNING
- This comparison is a snap shot of independent runs of MCNPX and PHITS in production like runs.
- PHITS was run with too little particles to be a conclusive performance benchmark.
- This is the first of a kind comparison and it only illustrates possible sources of discrepancies or inconsistencies.

Highlights

- Two different cases are compared:
  - Two-Step target with1.2GeV deuteron source – ANL design.

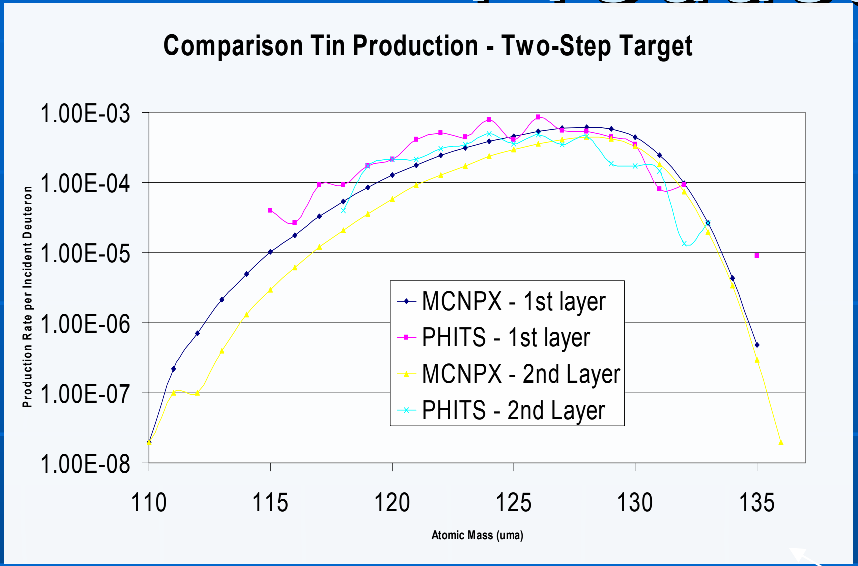
  - Barrel Beam dump with 320MeV/u Uranium Beam, 305kW power with Water as the stopping medium.

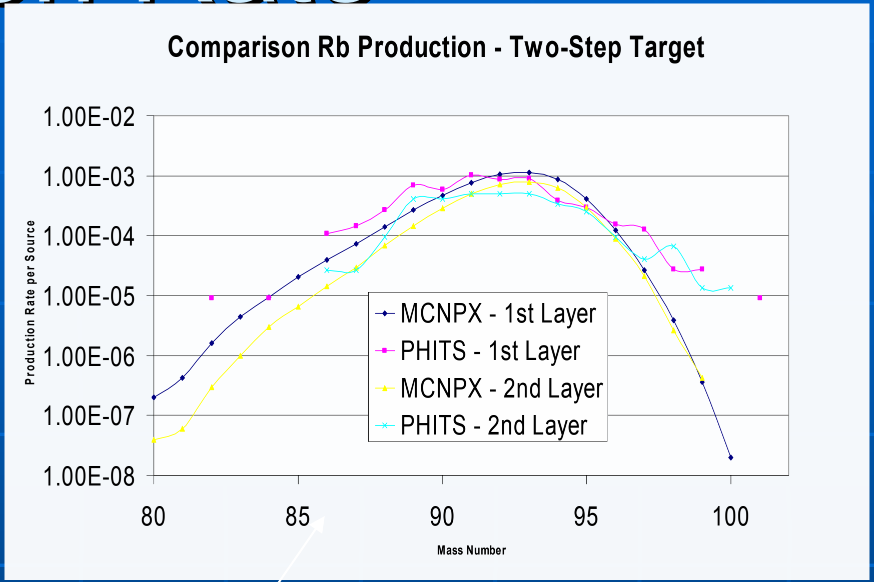


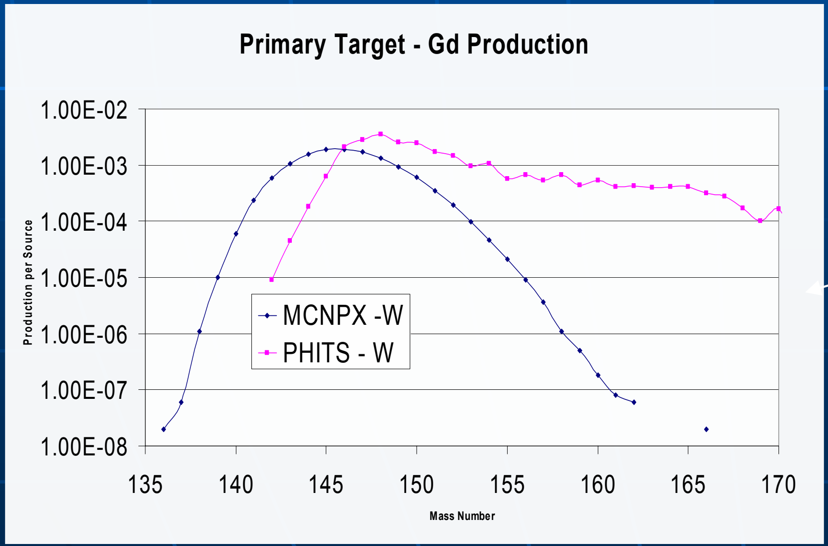
Two-step Target

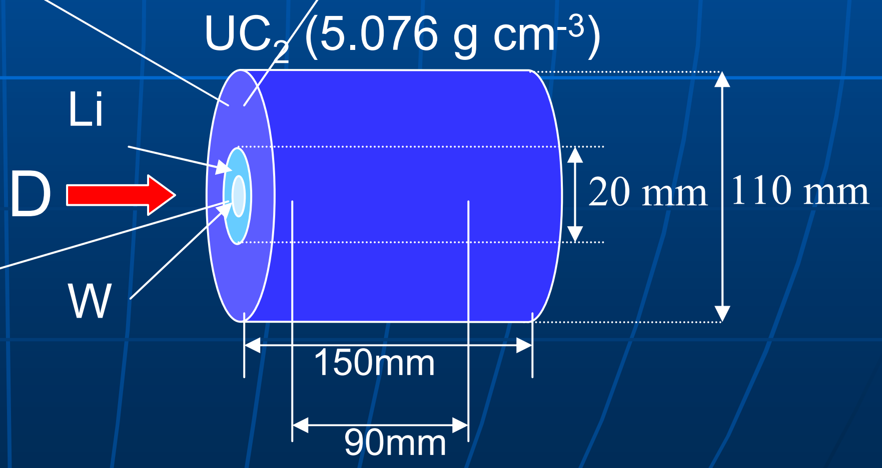
- MCNPX was run using the ISABEL nuclear model and ABLA fission model with 50,000,000 particles in 19:52hrs wall time with 32 processors.
- PHITS ran roughly 75,000 particles.

Production Rate



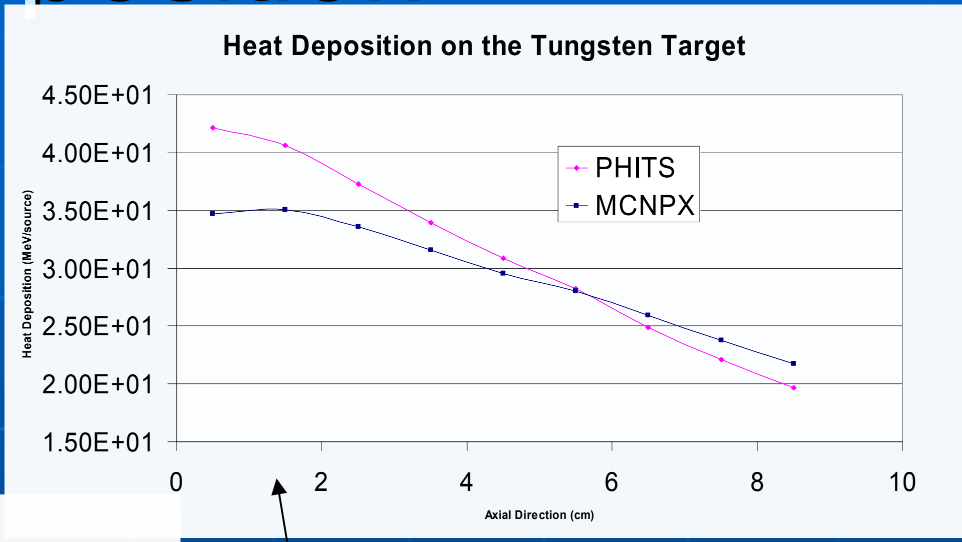


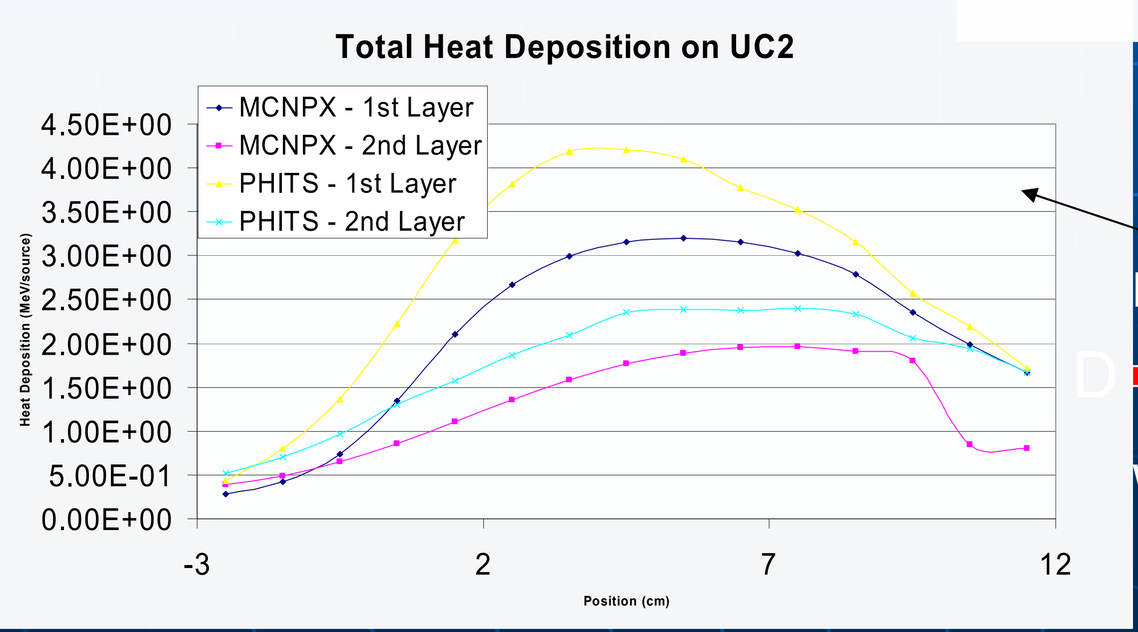




Heat Deposition

PHITS estimates a higher
Rate of Heat Deposition
in the Secondary
Than MCNPX – It may include
Below 20 MeV fission.





Fission Rate

- The total number of fission estimated in the secondary target is as follows:

PHITS:

1st layer = 0.135 per source

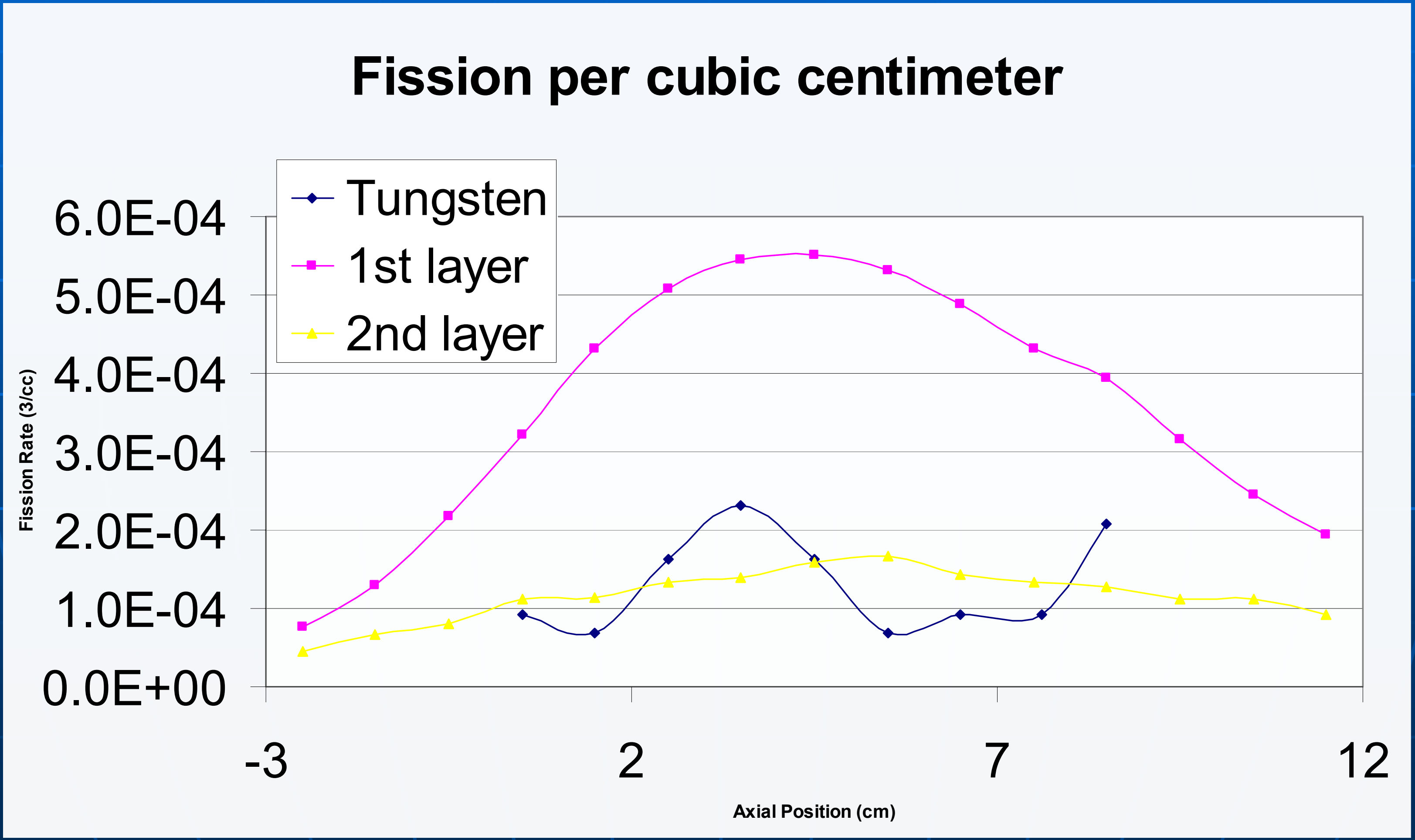
2nd layer = 0.098 per source

MCNPX:

1st layer = 0.059 per source

2nd layer = 0.048 per source

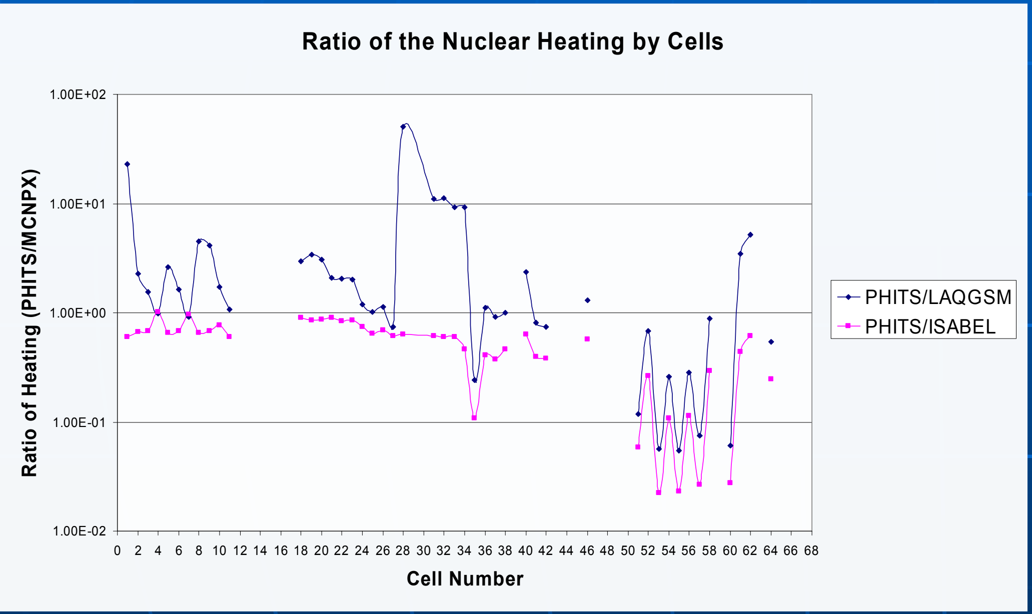
Fission Distribution in PHITS



Barrel Beam Stop

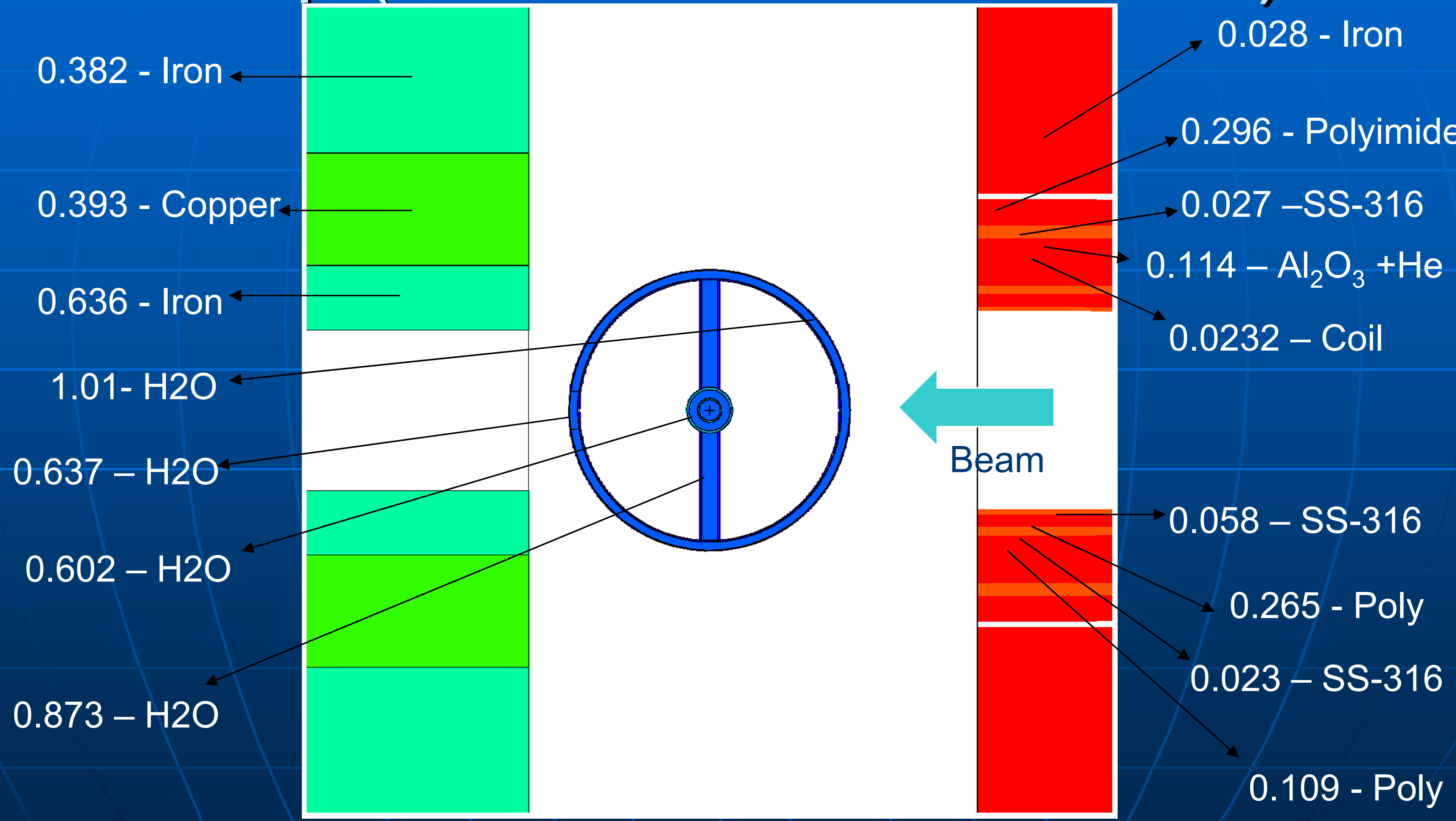
- The model is a 320 MeV/u uranium beam hitting a Aluminum barrel containing fast flowing water with a thickness of 2-cm.
- The uranium beam is stopped into the water after entering through a 0.2-cm aluminum window.
- The total beam power is roughly 305kW that is ~80% deposited into the water.

Nuclear Heating Comparison

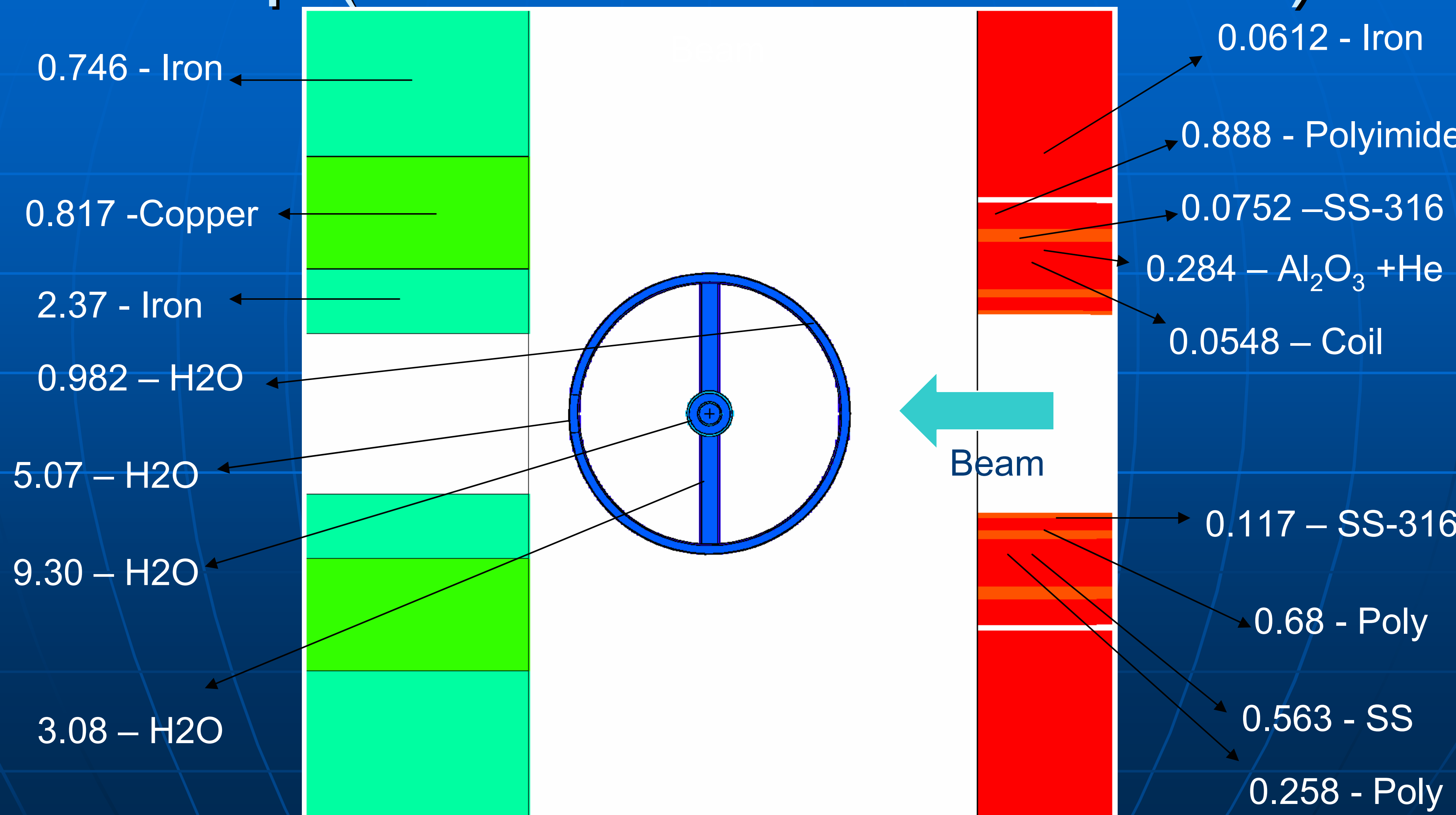


- MCNPX has run more than 1M particles; PHITS only 50,000 part.
- MCNPX using ISABEL model predicts more heating deposition than PHITS over all geometry.
- MCNPX using LAQGSM (without fission) mostly underestimates the heat deposition over all geometry.

Nuclear Heating Ratios – Beam Stop (PHITS/MCNPX-ISABEL)



Nuclear Heating Ratios – Beam Stop (PHITS/MCNPX-LAQGSM)



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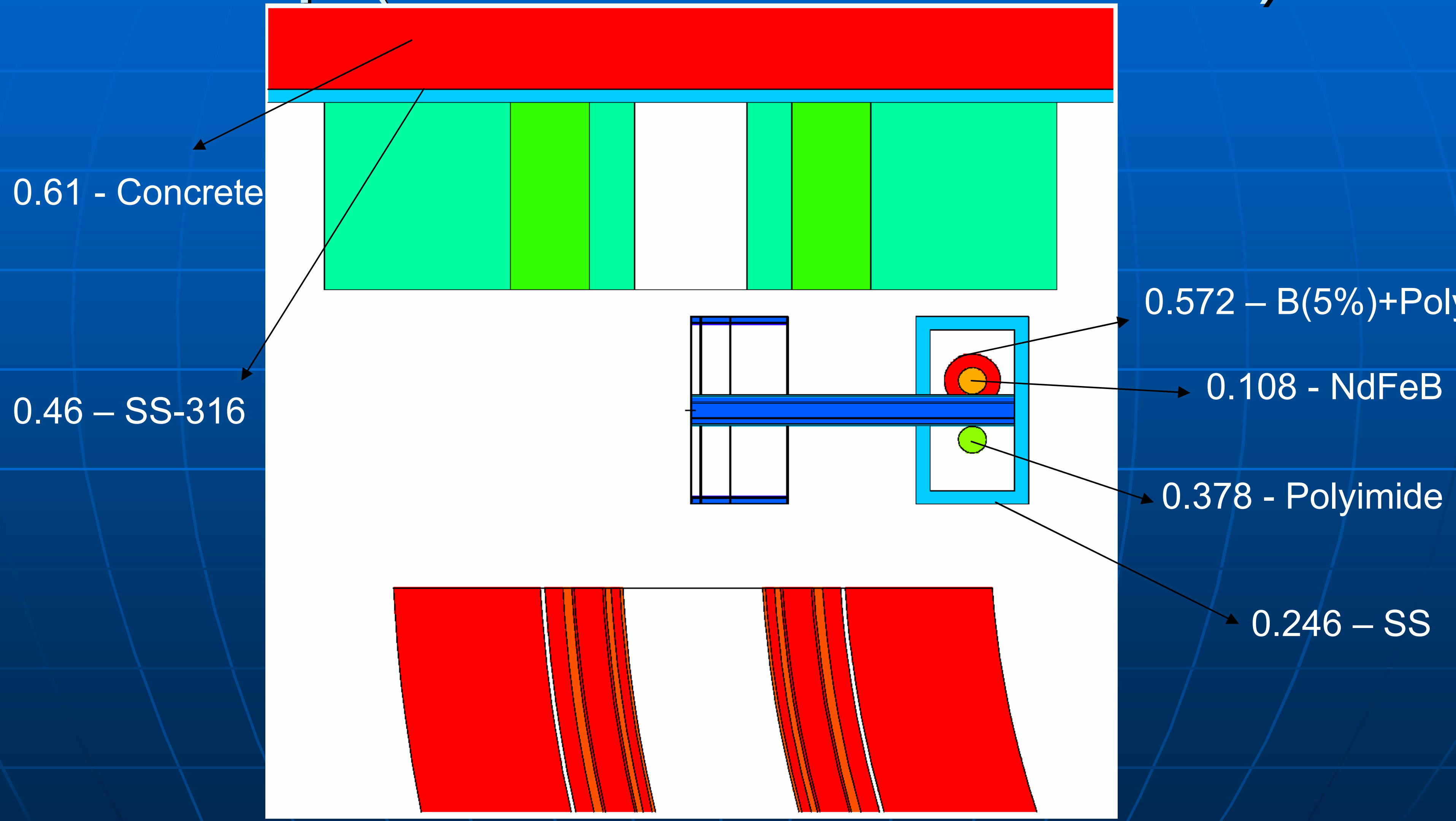
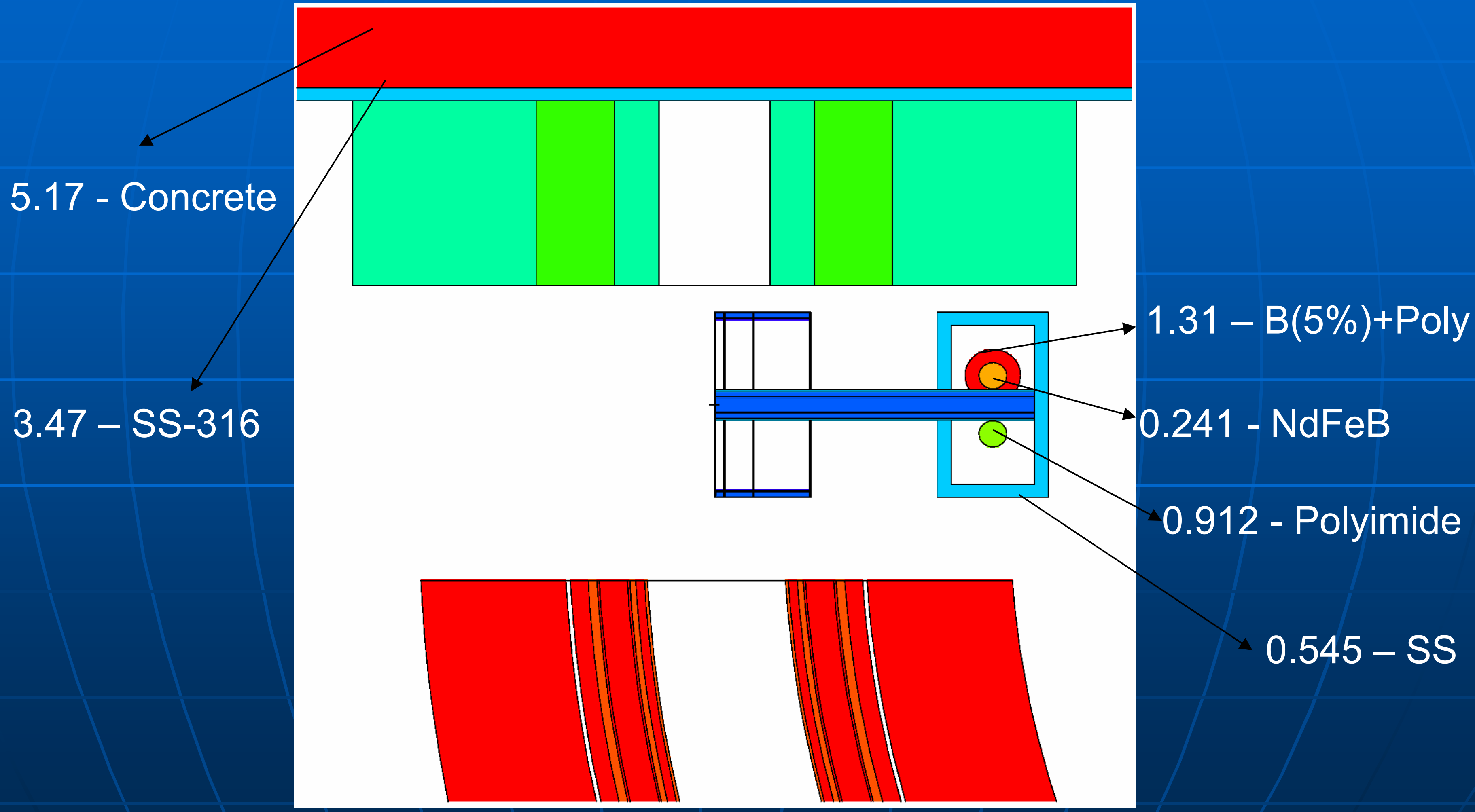
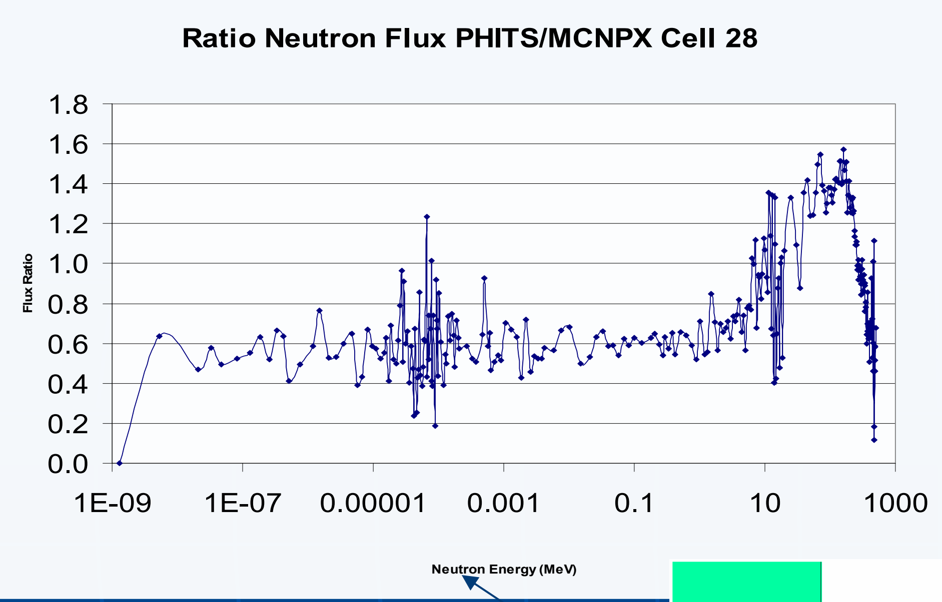
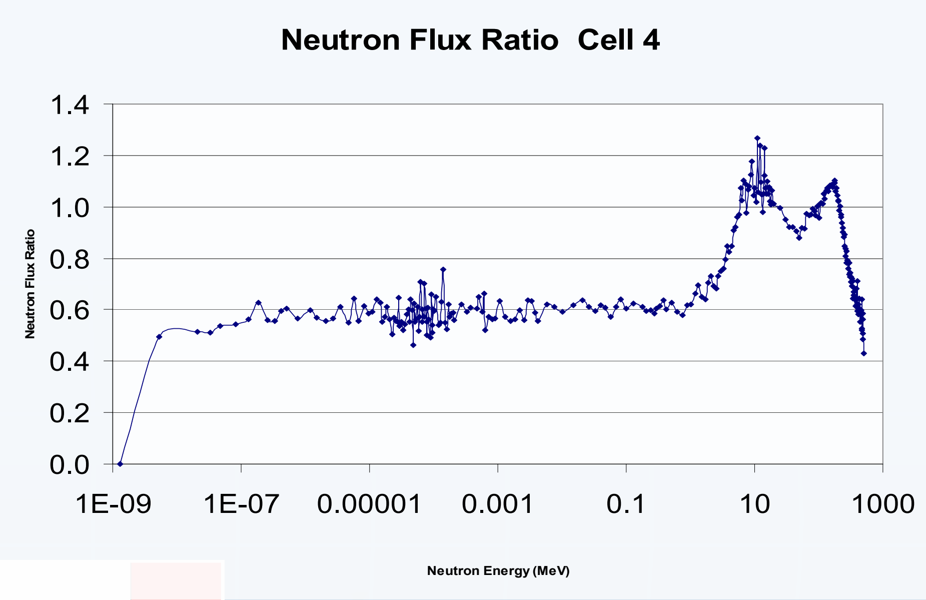


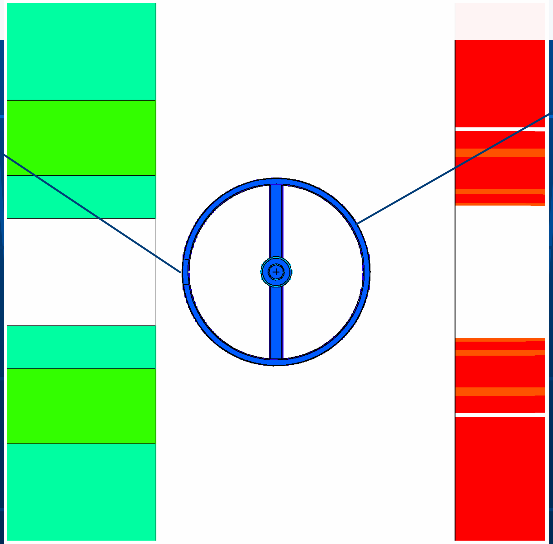
Nuclear Heating Ratios – Beam Stop (PHITS/MCNPX-LAQGSM)



Comparison of the Ratio of Neutron Flux at Selected Regions



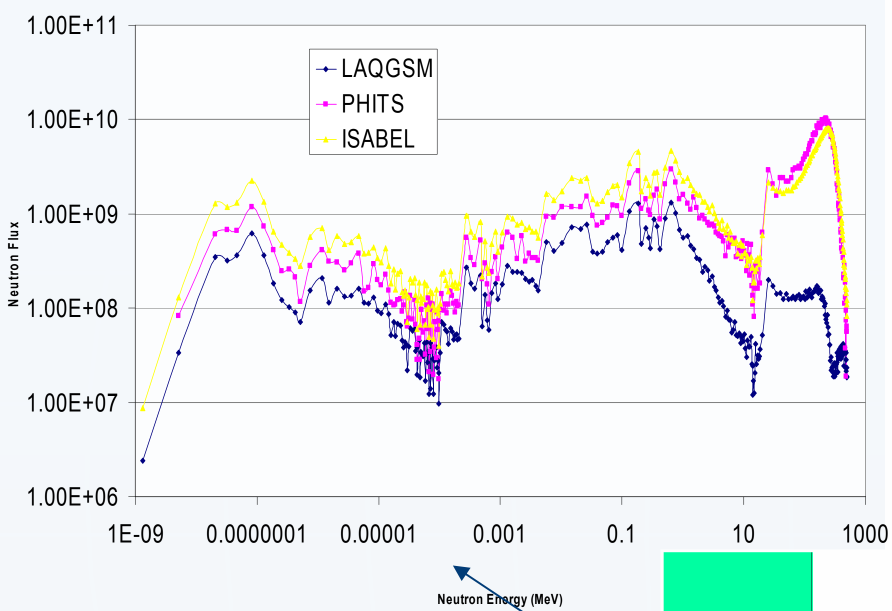


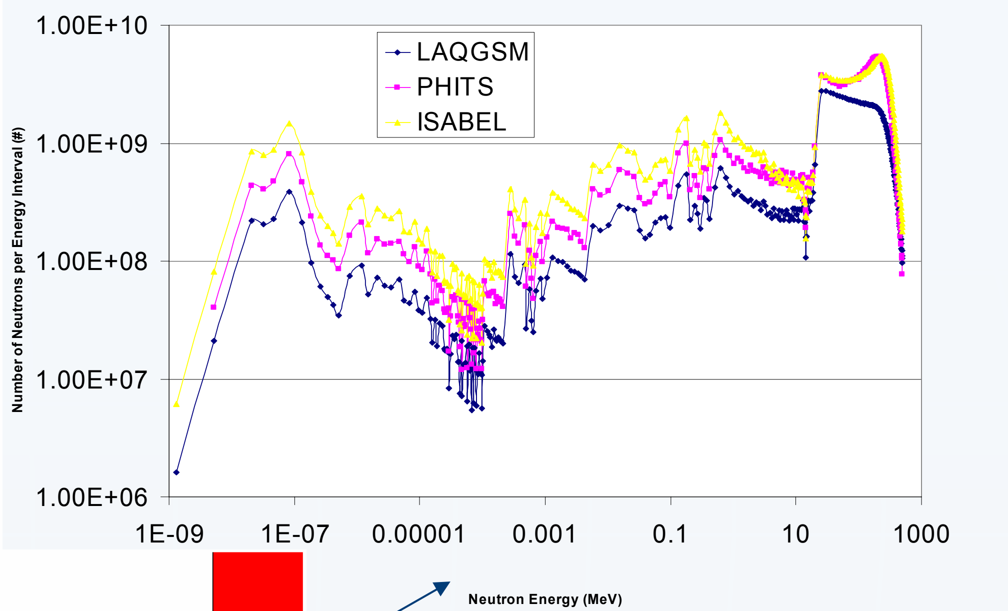


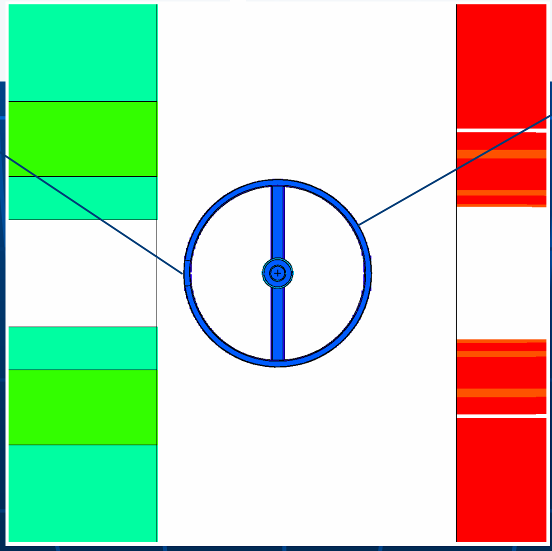
Neutron Flux Averaged Over a small cell in the Forward Direction of The Point where the Hits the Barrel.

Neutron Flux Averaged Over the Cell that the Beam Hits – dominated By the production from the beam interaction.

Comparison of the Neutron Flux at Selected Regions







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Neutron Flux Averaged Over the Cell that the Beam Hits – dominated By the production from the beam interaction.

Fission Yields – Beam Stop

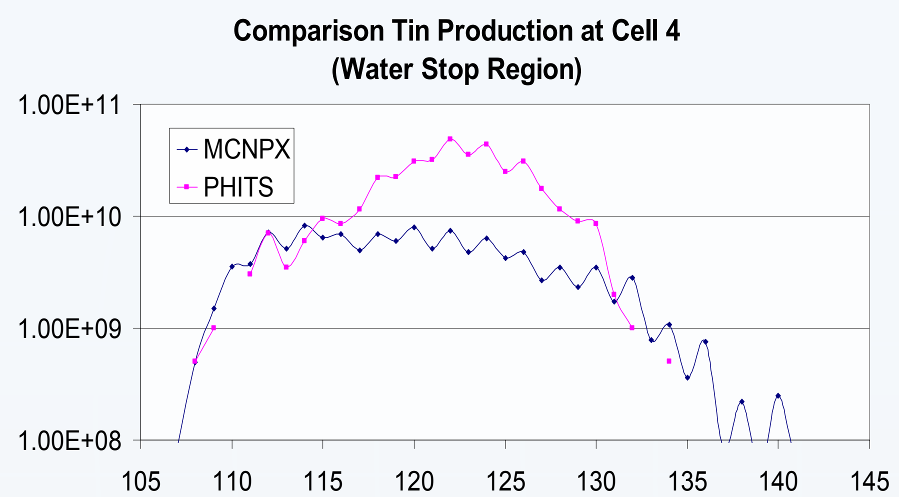
- Total Number of Fission (Estimated by the Residual Mass from Z 12 to 70)

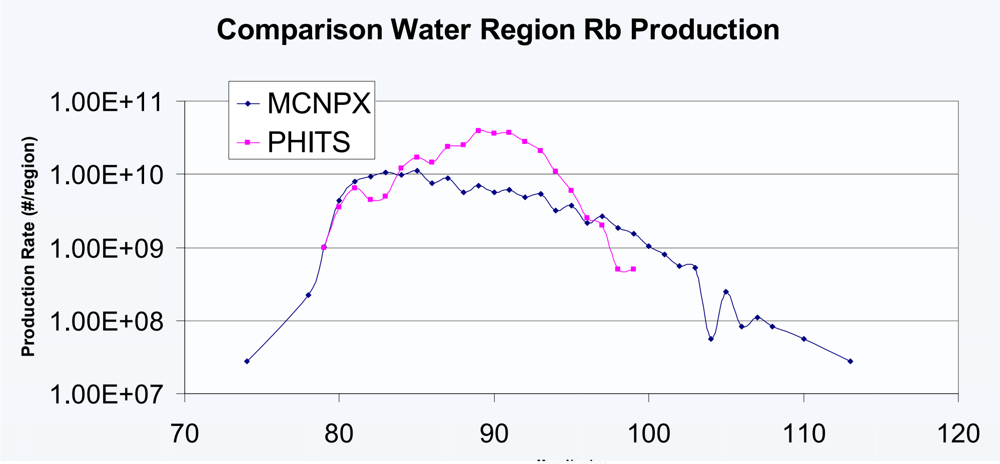
  PHITS = 18.75 % of incident U-238 fission

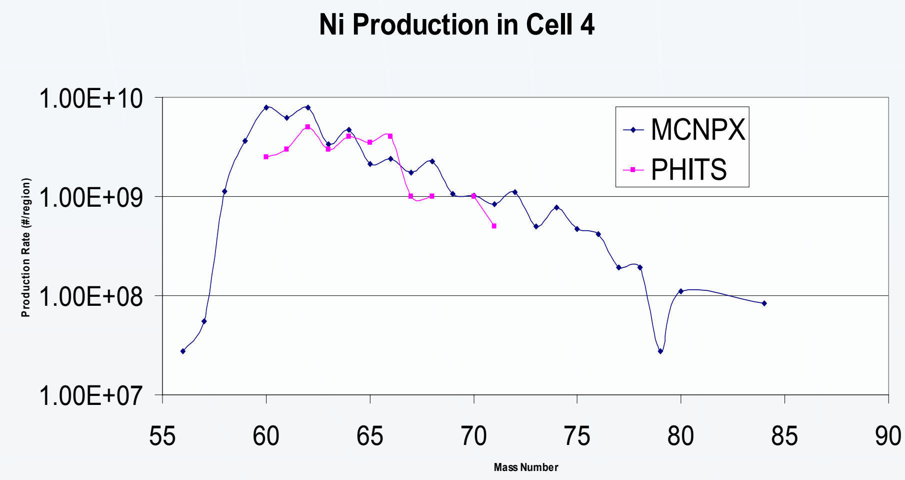
  MCNPX = 8.88% of incident U-238 fission

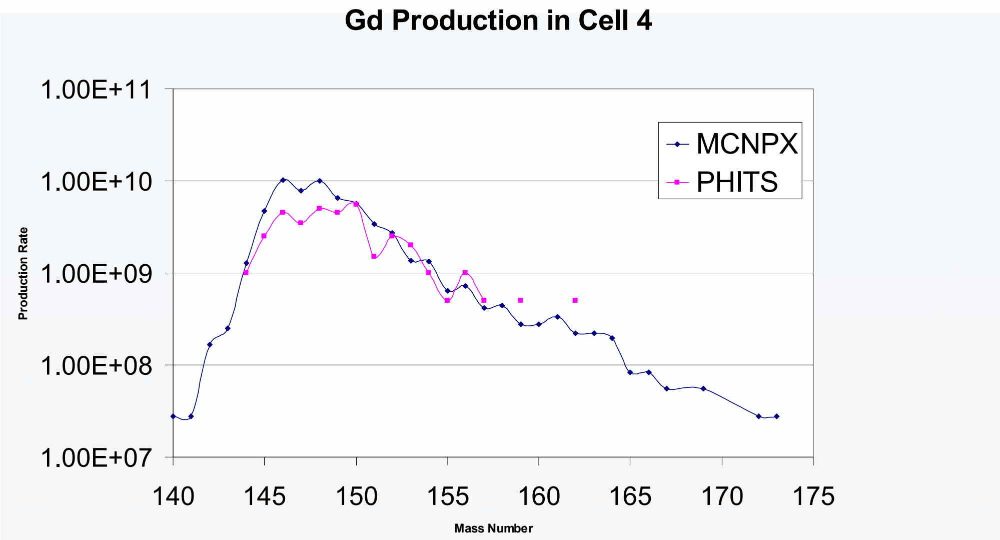
  These numbers assume 2 fragments per fission.
- A possibility is that PHITS allows fission at a lower excitation level – characteristic of below 20-MeV interactions – just a guess.
- MCNPX uses ABLA fission model.

Selected Fission Products Comparison









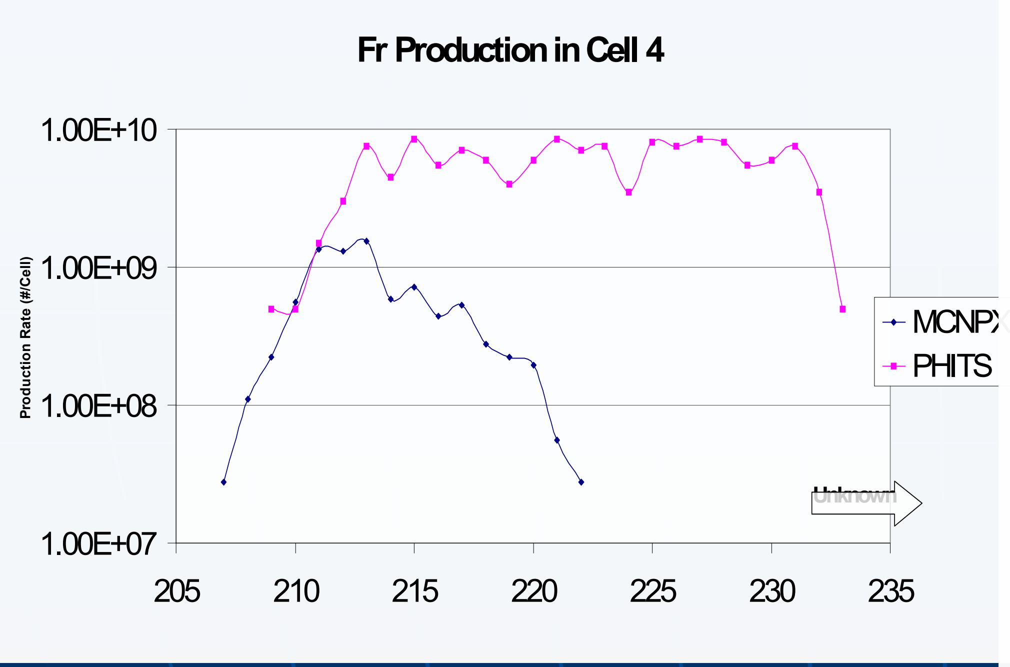
"Spallation" Region Yields

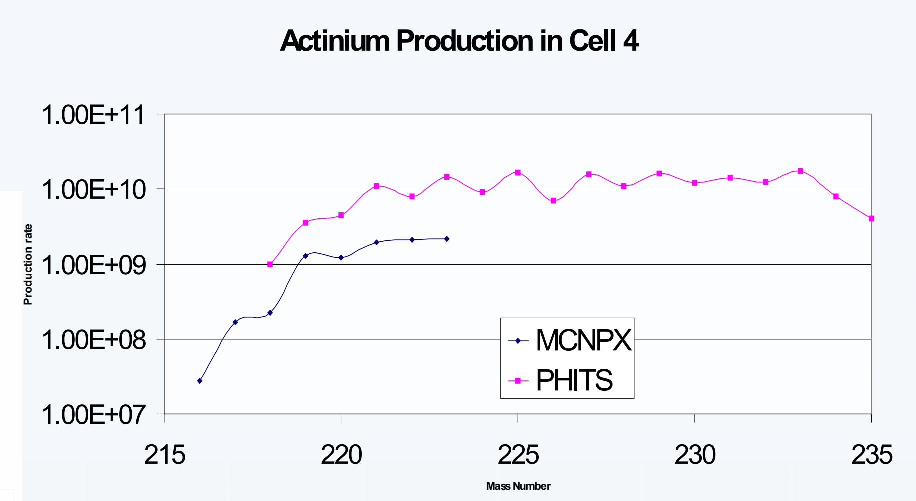
- Total Number of Spallation Products (Estimated by the Residual Mass from Z 71 to 99)

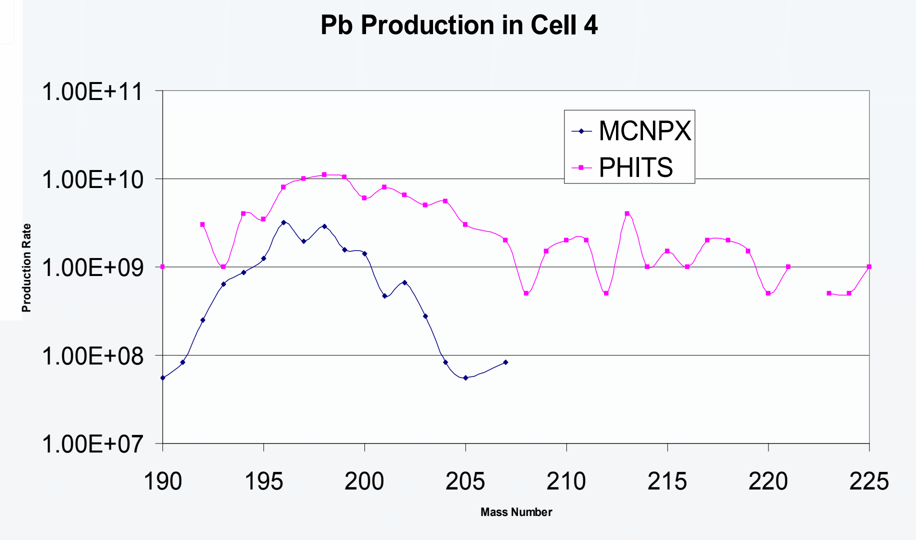
  PHITS = 11.8% of incident U-238 undergo nuclear reactions

  MCNPX = 3% of incident U-238 undergo nuclear reactions
- A problem seems that MCNPX underestimates spallation products and PHITS overestimates production of very neutron rich isotopes. By example Pb is listed in the isotopic table up to 214 and PHITS predicts abundant production up to 225 mass.

Selected "Spallation" Products





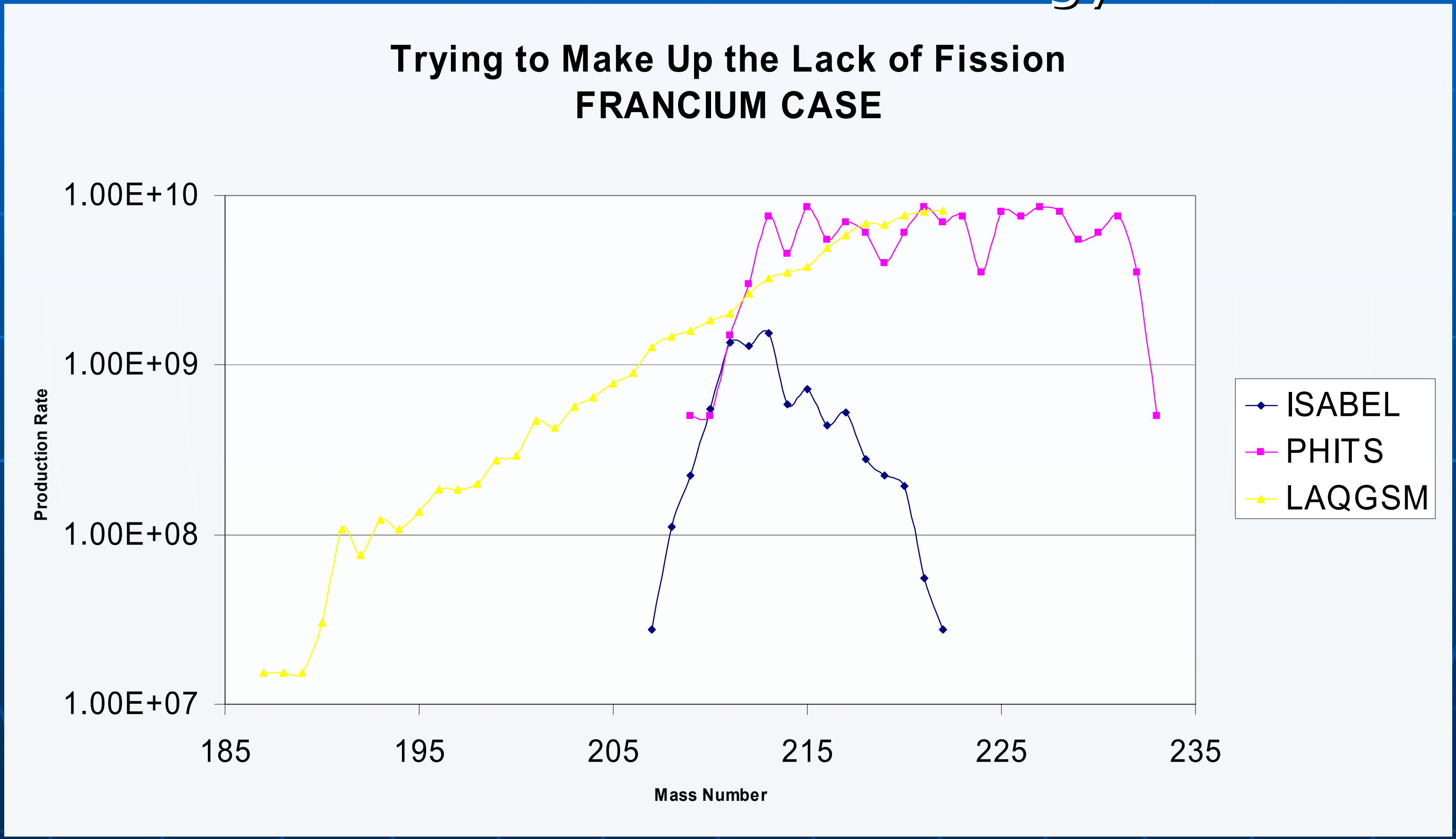


Comparison of Products at Water Beam Stop Region

	PHITS	ISABEL	LAQGSM
Neutrons	1.48E+14	1.27E+14	4.57E+13
H-1	5.51E+13	5.01E+13	2.48E+13
H-2	7.49E+12	9.92E+12	1.22E+12
H-3	2.45E+12	5.87E+12	1.27E+12
He-3	1.02E+12	2.32E+12	8.35E+11
He-4	6.04E+12	1.43E+13	3.55E+12

Things that We Learned

- LAQGSM without a fission channel evaporates neutrons to release excess energy.



Conclusions

- This comparison has shown that there is room for improvement for both codes.
- MCNPX needs to implement fission to the LAQGSM option to allow a fair comparison.
- PHITS seems to have a problem in the "spallation region" where the products seem to be unrealistically neutron rich. This may affect other parts of the calculation because not enough neutrons are being emitted leaving an excess of energy in the excited compound nucleus.
- This comparison is too preliminary to be conclusive.
- The low number of particles run in the PHITS cases may have affect the results.
- Not all options of PHITS or MCNPX were used, what also may have affect the results.

Heat Deposition not here

- Water
- Heating= 1.22e+05 MeV/g
- $Q = m * Cp * \Delta T \Rightarrow Q/m = Cp * \Delta T$
- Cp = 4.186 J/gC
- Q/m = 1.22e+05*2.5e+13*1.602e-13
- Q/m = 4.8861e+05 W/g => Q/m=488.6 J/g
- $\Delta T = 116.7\ ^{o}C$
- Al => Q/m = 3.08e+04MeV/g=>246.8J/g
- Cp= 0.9 j/gC => $\Delta T = 274\ ^{o}C$ melts 660 ^{o}C