# Applying New Variance Reduction Methods in Shift

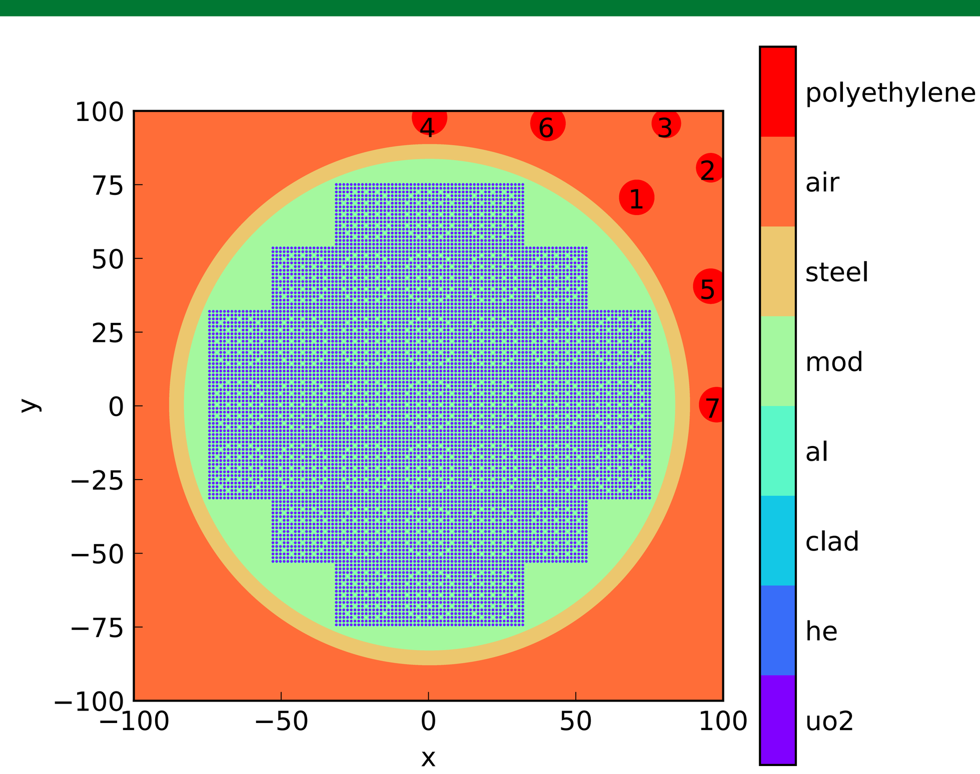

Evan S. Gonzalez – University of Michigan

**Mentor:** Gregory G. Davidson **Program:** NESLS **Group:** Radiation Transport **Division:** Reactor and Nuclear Systems Division


## Background

- **Shift** is a Monte Carlo (MC) radiation transport code under development as a part of the SCALE suite of nuclear reactor modeling codes
- MC methods
  - Provide very accurate solutions
  - Are computationally expensive (require many particle histories for low statistical uncertainties)
- Uncertainties can be reduced by introducing copies of particles into the simulation and adjusting their *weight* in the final solution
  - Upon various events in a particle's history, a particle can be *split* (more copies introduced) or *rouletted* (particle history is terminated) by sampling a random number and comparing its value to the particle's weight
- Hybrid variance reduction (VR) methods (coupling with a deterministic radiation transport code) have been implemented in Shift to generate *weight windows*
  - VR is used to determine the importance of a region in the problem and to refine splitting/rouletting
- Optimization of events in a particle's history in which splitting/rouletting are implemented is largely unexplored
  - This project involved implementing new VR methods into Shift and analyzing their effectiveness

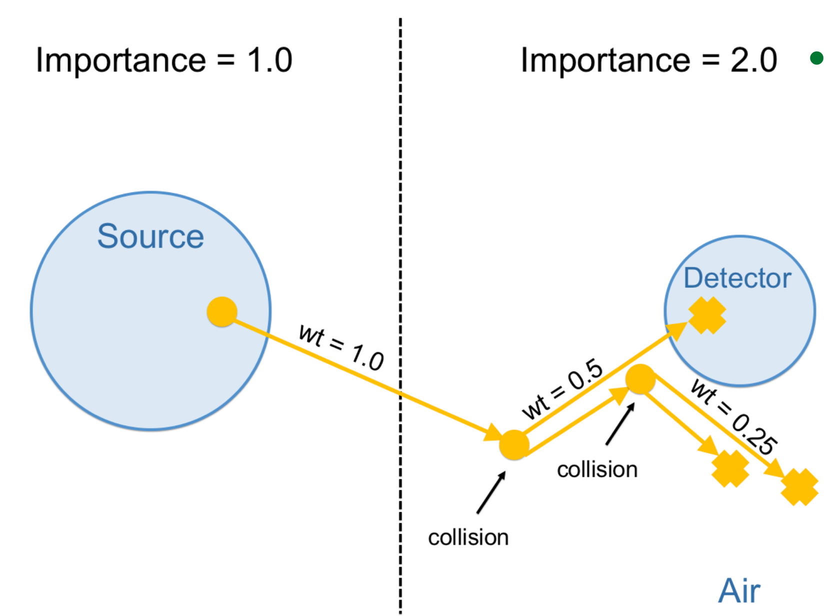
## Test Model



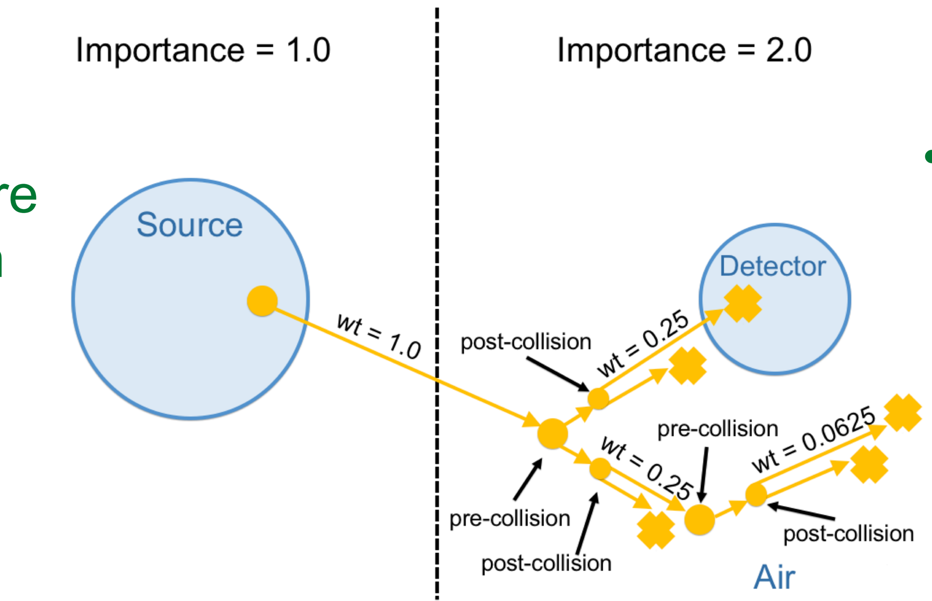

- VR methods + *analog Monte Carlo* (no VR methods imposed) and *Rouletting* (no hybrid-generated weight windows) were run on a small PWR core with seven excore Bonner spheres serving as detectors
- All VR methods applied FW-CADIS for weight window generation and implemented full source biasing

## Splitting/Rouletting Methods

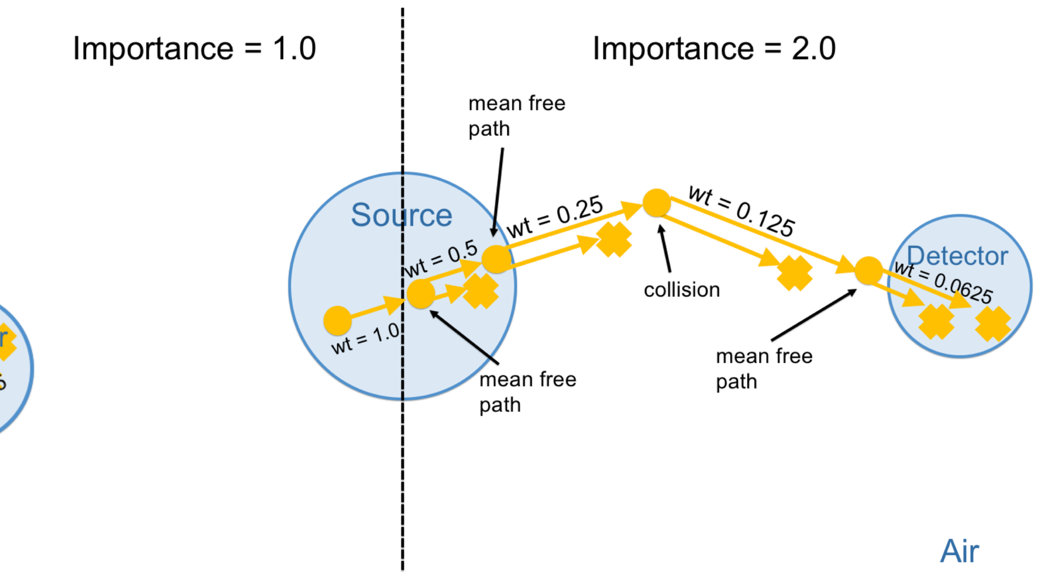
- **Post-Collision (previously in Shift):**
  - Process variance reduction after collision mechanics have been called



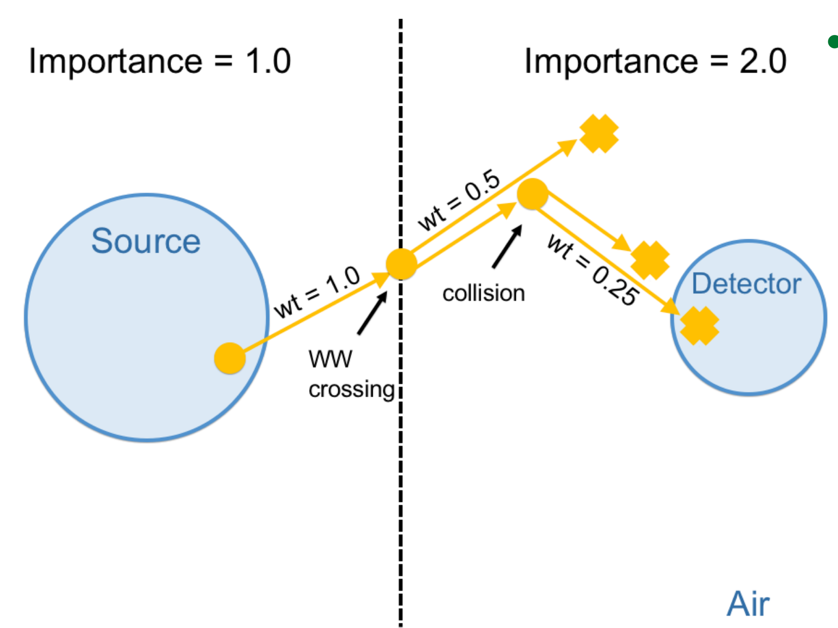

- **Pre- and Post-Collision:**
  - Process VR before and after collision mechanics have been called



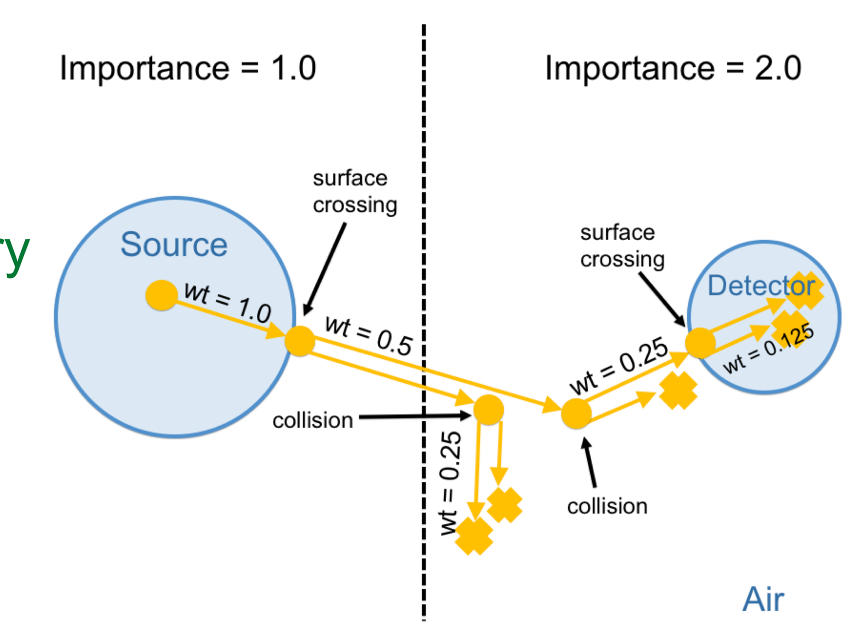

- **Mean Free Path-Collision:**
  - Process VR after traversing one mean free path and after collision mechanics have been called




- **Tracking-Collision (previously in Shift):**
  - Process variance reduction after crossing weight window and after collision mechanics have been called




- **Surface Crossing-Collision:**
  - Process VR after crossing geometry surface and after collision mechanics have been called

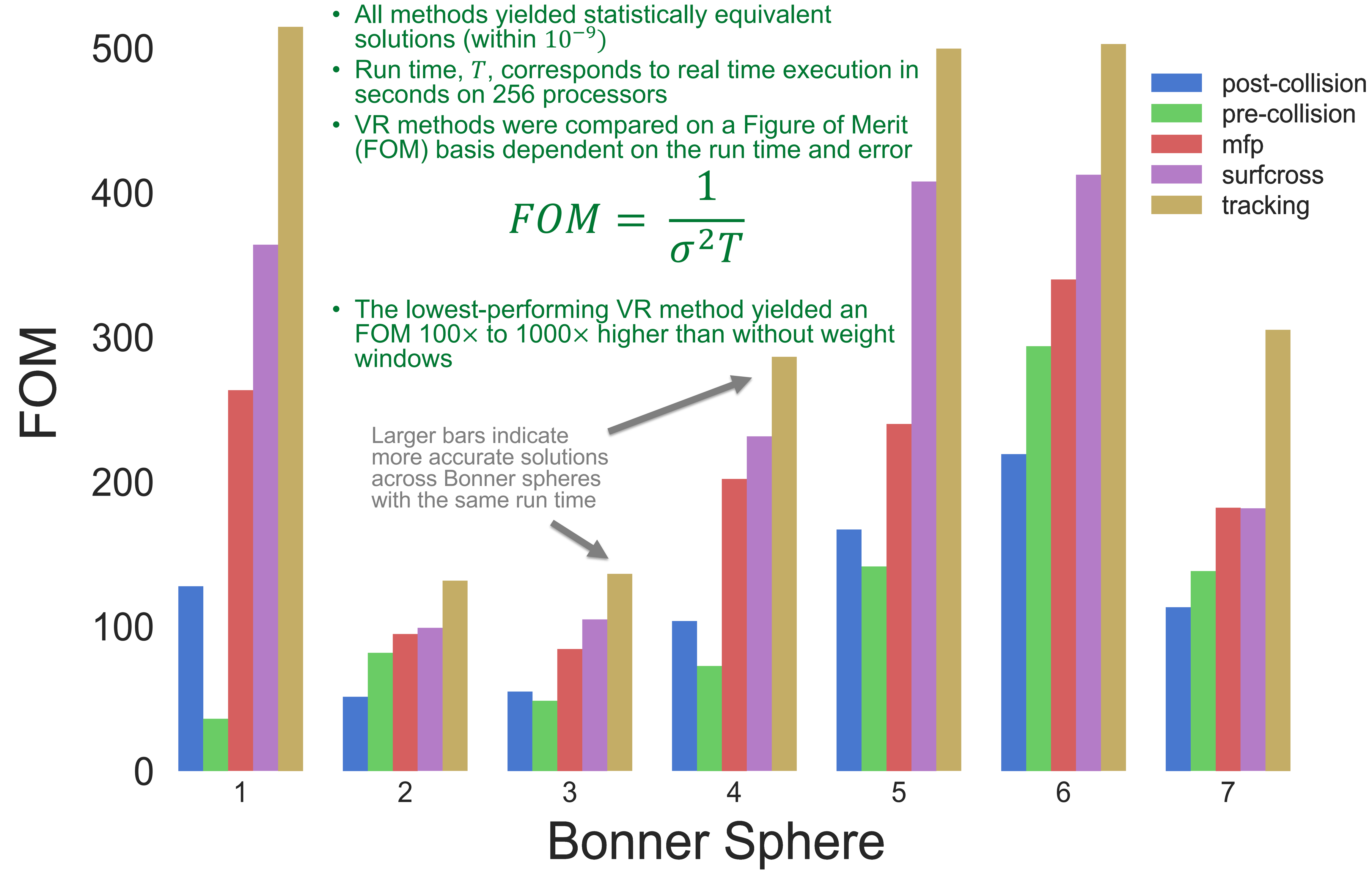



## Results

- All methods yielded statistically equivalent solutions (within $10^{-9}$)
- Run time, $T$, corresponds to real time execution in seconds on 256 processors
- VR methods were compared on a Figure of Merit (FOM) basis dependent on the run time and error

$$FOM = \frac{1}{\sigma^2 T}$$

- The lowest-performing VR method yielded an FOM 100× to 1000× higher than without weight windows




## Conclusions

- The tracking-collision method remains the most effective variance reduction process by the figure of merit
- Both the mean free path-collision and surface crossing-collision methods proved to be more computationally efficient than the post-collision method
- The pre-collision method yielded comparable results to the post-collision method

## Future Work

- Newly-implemented methods are in the process of being tested on different models in which the parameters of interest might vary widely (e.g., MFP, number of surfaces, etc.)
  - It is likely that the relative performance of the different methods will depend on the type of problem being analyzed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