OAK RIDGE National Laboratory

# MAVRIC course review and outlook

## SCALE 6.3.1

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

# Learning goals

- Summarize what has been covered by the Monaco/MAVRIC training and identify how these topics were applied in the different exercise problems
- Identify a few topics that were not covered during this training that attendees should be aware of
- Preview future feature development of Monaco/MAVRIC

# 1. Simple shielding simulations

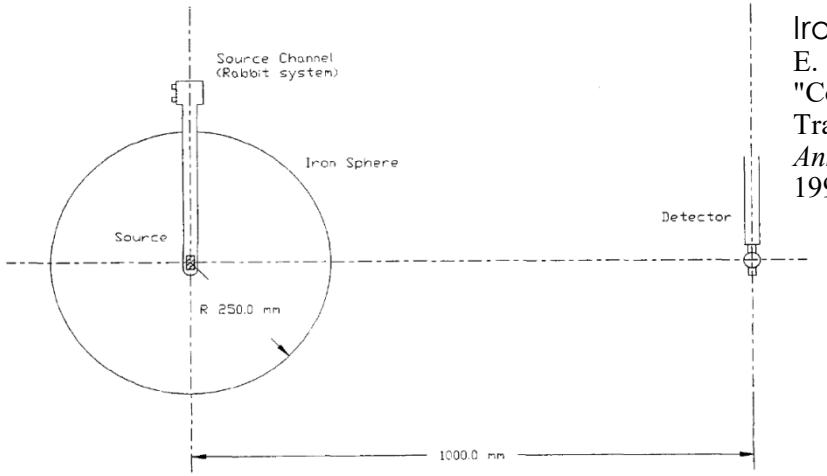
- Shielding calculations: Monte Carlo basics
  - Statistical nature of MC
  - Variance reduction (VR)

- Elements of a shielding calculation
  - Physical model, sources, tallies, parameters

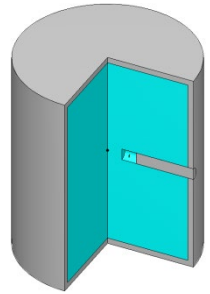
- Monaco/MAVRIC
  - Block/keyword input; shares many blocks with KENO-VI
  - Output: main text file, tally files, statistical tests

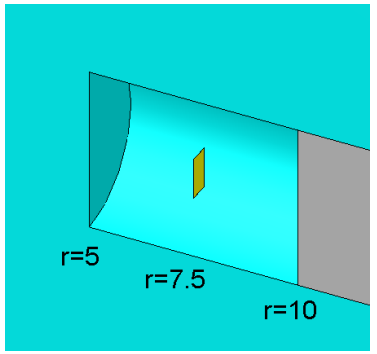
# 1. Simple shielding simulations

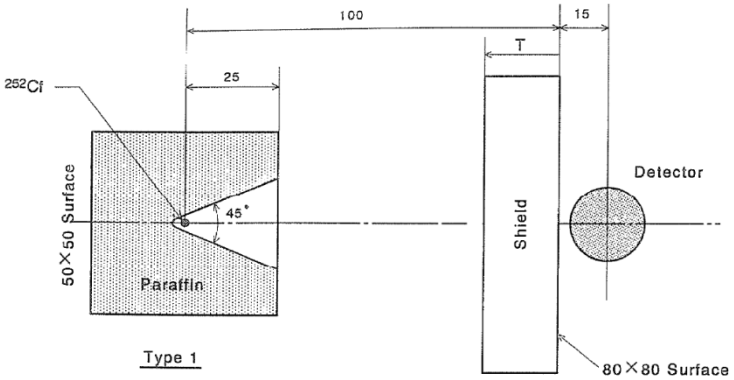
- Exercise problems
  - Iron sphere benchmark
  - Activation of a gold foil
  - Ueki shielding measurements
    - Saw the need for VR




Iron sphere experiments
E. Sajo, et al.,
"Comparison of Measured and Calculated Neutron Transmission Through Steel for a 252Cf Source,"
*Annals of Nuclear Energy,* vol. 20, no. 9, pp. 585- 604, 1993.






Ueki shielding measurements
K. Ueki et al.,
"Systematic Evaluation of Neutron Shielding Effects for Materials," Nuclear Science and Engineering, vol. 124, no. 3, pp. 455-464, 1996.

# 2. CADIS: Automated in MAVRIC

- Consistent Adjoint Driven Importance Sampling
  - Discussed the use of importance maps in general
  - Showed mathematical basis for CADIS

$$q^+(\vec{r},E) = \sigma_d(\vec{r},E) \qquad \phi^+(\vec{r},E)$$

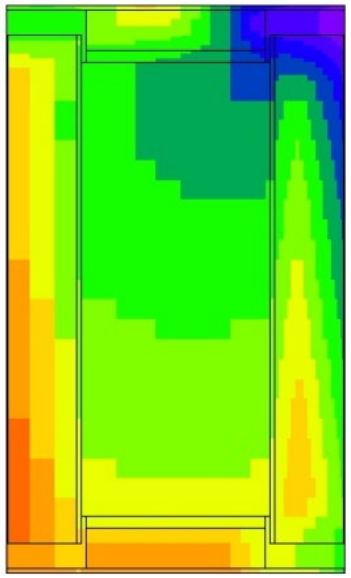
$$R = \int_{V_S}\int_{E} q(\vec{r},E)\,\phi^+(\vec{r},E)\,dE\,dV$$

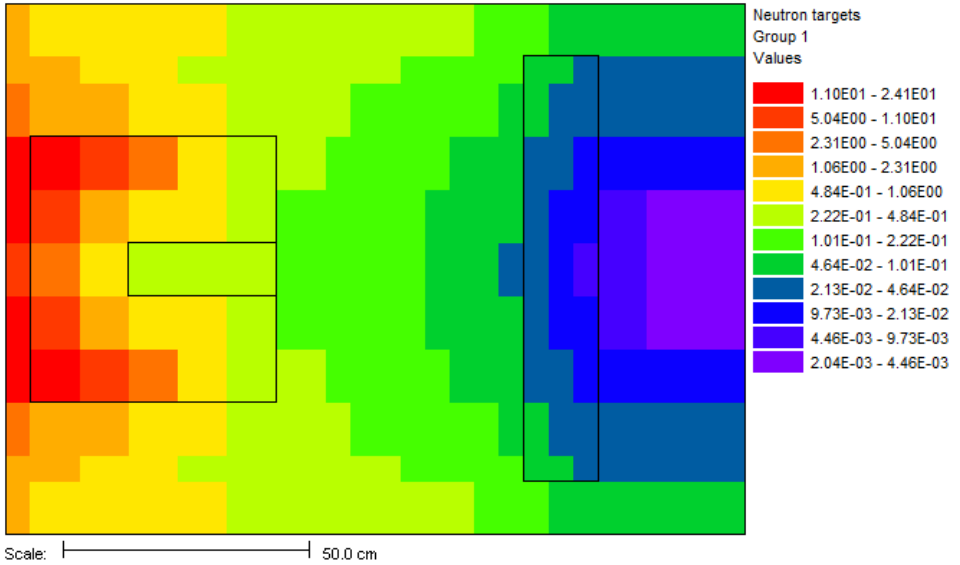
$$\overline{w}(\vec{r},E) = \frac{R}{\phi^+(\vec{r},E)} \qquad \hat{q}(\vec{r},E) = \frac{1}{R}q(\vec{r},E)\phi^+(\vec{r},E)$$

- Monaco/MAVRIC
  - importanceMap block for using CADIS-based VR
  - MAVRIC uses Denovo $S_N$ code for fast adjoints

# 2. CADIS: Automated in MAVRIC

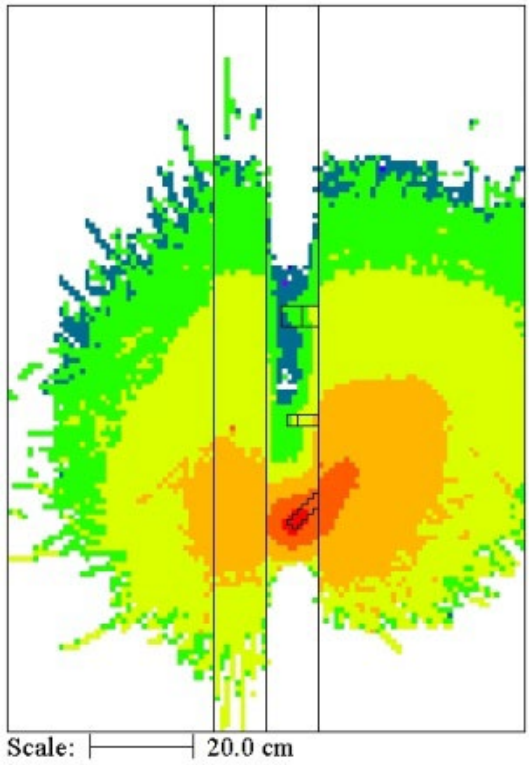
- Exercise problems
  - Shipping cask
  - Ueki revisited





# 3. FW-CADIS

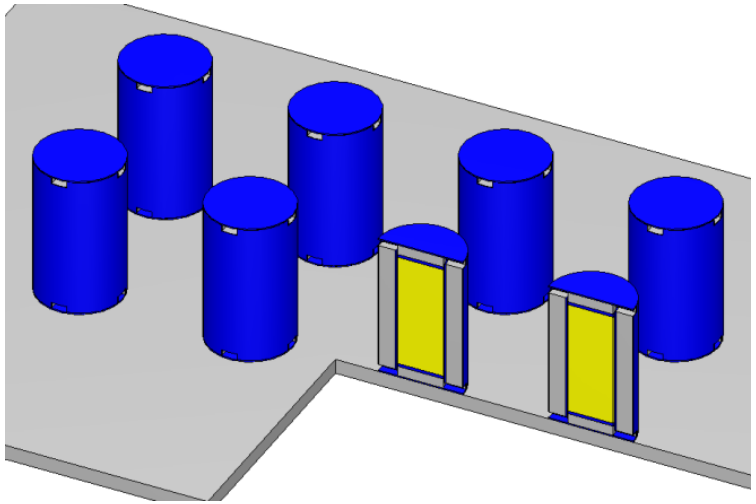
- Forward-Weighted CADIS
  - Optimize several tallies at once
  - Obtain more uniform relative uncertainty for mesh tallies
  - Different "flavors" depending on what is to be optimized

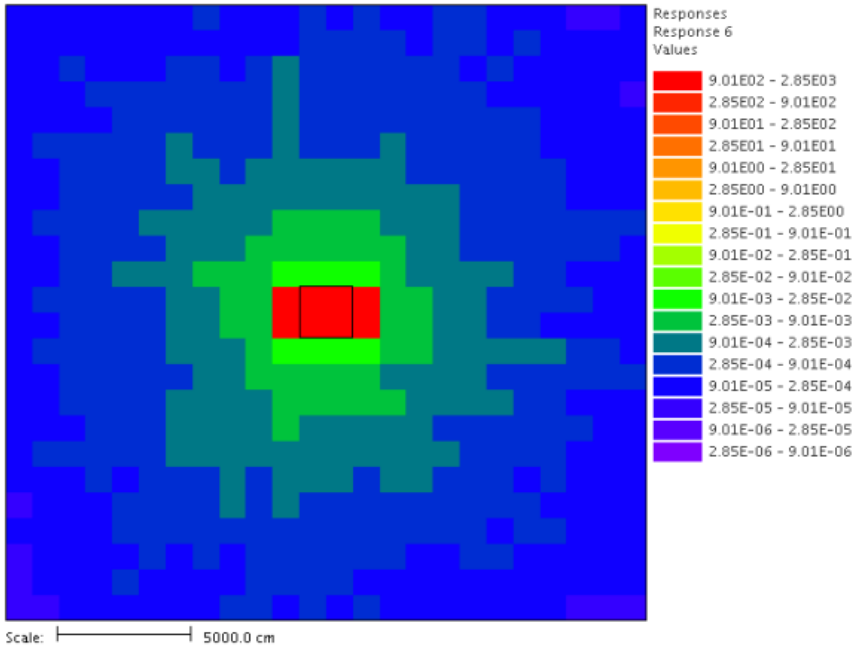


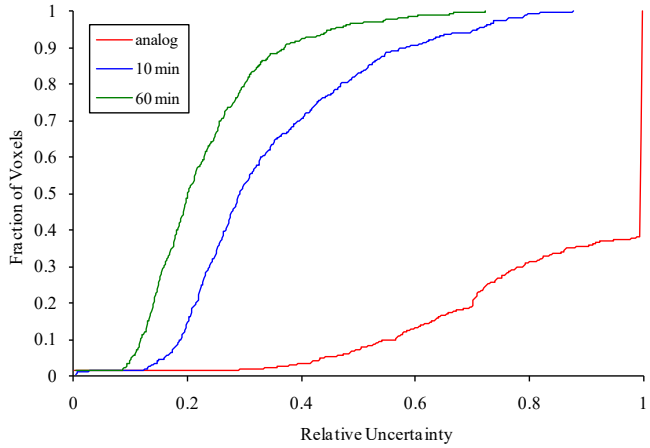

| For the optimization of: | Use adjoint source: |
|---|---|
| $\phi(\vec{r},E)$ | $q^{+}(\vec{r},E)=\frac{1}{\phi(\vec{r},E)}$ |
| $\int \phi(\vec{r},E)dE$ | $q^{+}(\vec{r},E)=\frac{1}{\int \phi(\vec{r},E)dE}$ |
| $\int \phi(\vec{r},E)\sigma_d(\vec{r},E)dE$ | $q^{+}(\vec{r},E)=\frac{\sigma_d(\vec{r},E)}{\int \phi(\vec{r},E)\sigma_d(\vec{r},E)dE}$ |

# 3. FW-CADIS

- Exercise problem
  - Cask farm
  - (used an ORIGEN source)

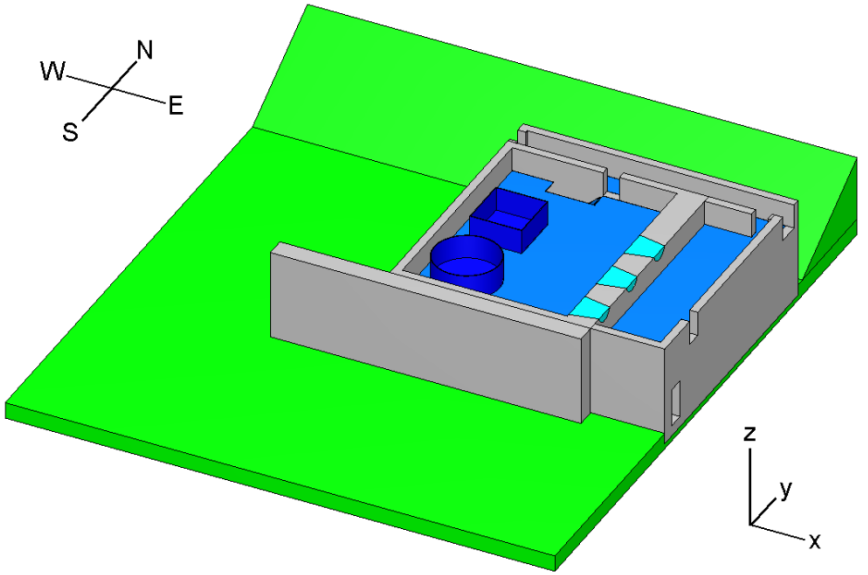


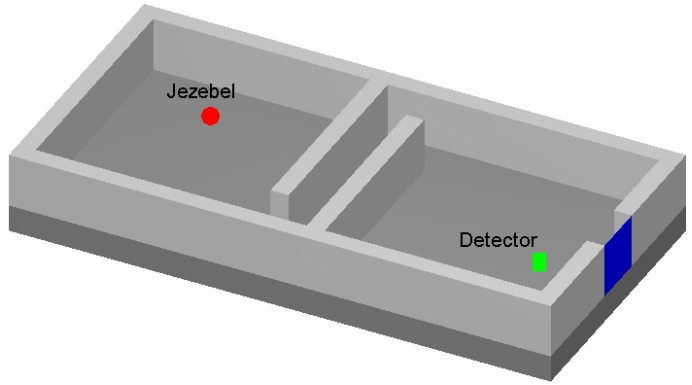


# 4. CAAS capability

- Combine KENO-VI and MAVRIC
  - Use KENO-VI to compute $k_{eff}$ and save a mesh tally
  - Convert mesh tally to a mesh source
  - Use mesh source in MAVRIC
- Options
  - Simulate fission photons and neutrons
  - Several input files or one input file
- Exercise problems

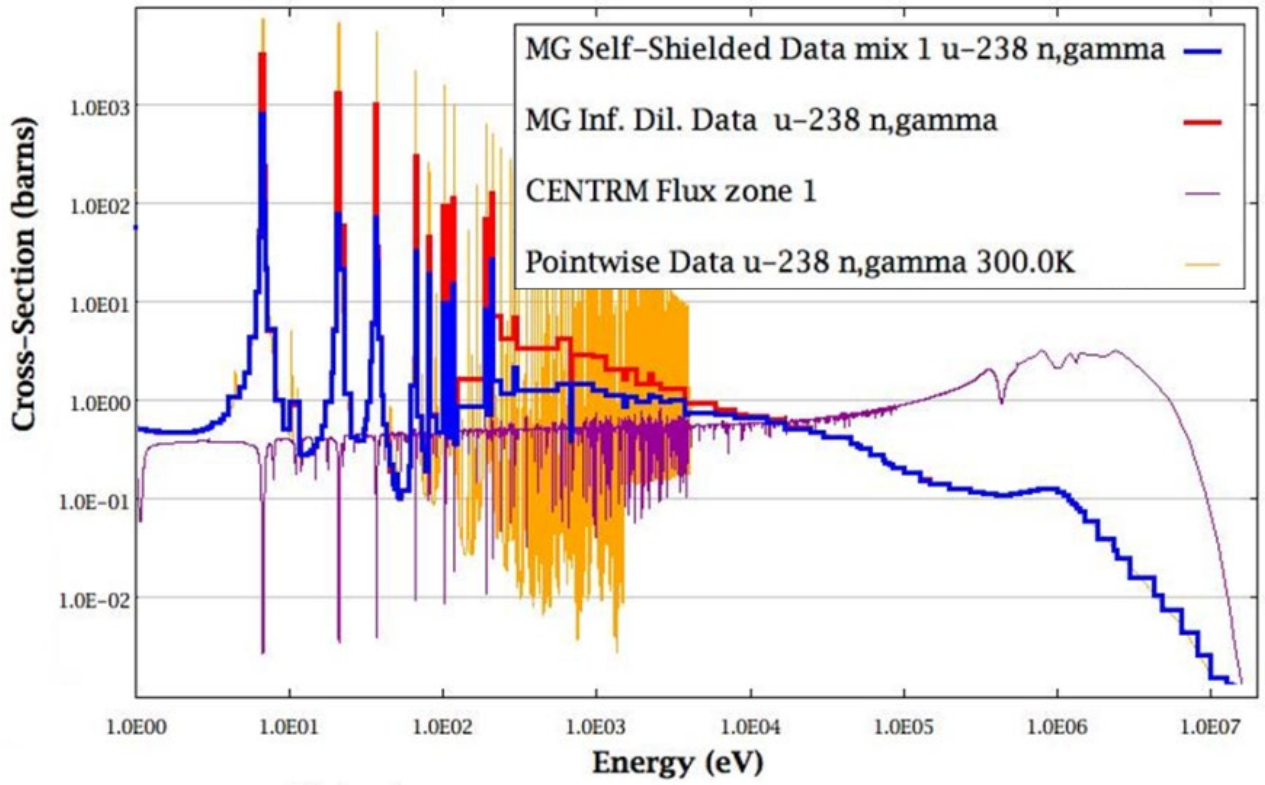


# Not covered in training class

```
=mavric     parm=keyword
Some title for this problem
v7-27n19g

read compositon
   ...
end composition
read celldata
   ...
end celldata

read geometry
   ...
end geometry
read array
   ...
end array
read volume
   ...
end volume
read plot
   ...
end plot
```

```
read definitions
   ...
end definitions
read sources
   ...
end sources
read tallies
   ...
end tallies

read parameters
   ...
end parameters
read biasing
   ...
end biasing
read importanceMap
   ...
end importanceMap

end data
end
```




- CellData block
  - Resonance self-shielding for MG
  - May be needed for some shielding applications

# Example of celldata block

- Current experience has shown that the celldata block is needed by Monaco/MAVRIC when attempting to calculate the activation of a material using multigroup cross sections and the following is true
  - When the material is "thin" (not infinite homogenous)
  - The activation product is produced primarily by thermal neutrons (i.e., higher activation cross section at low energies than at high energies)
- The neutron howitzer exercise (gold foil activation) is an example of when the celldata block is needed for improved accuracy
- In the following table are results of the gold foil activation calculation with and without the celldata block using multigroup cross sections compared to a continuous-energy calculation

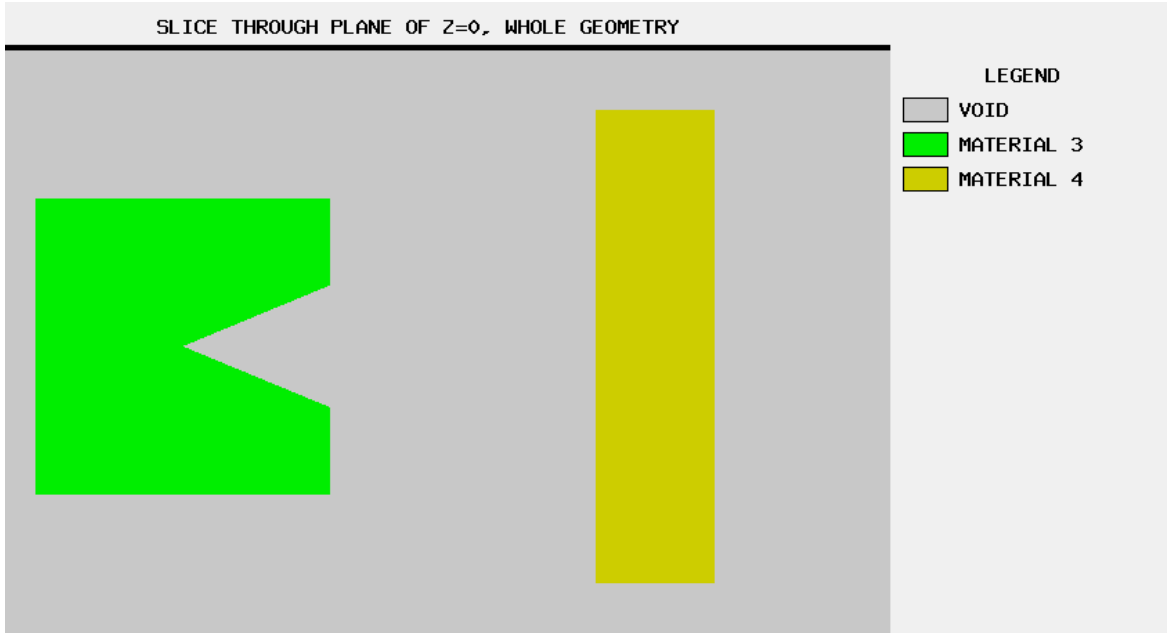
| Calculation Parameters | Activation Reactions (/cm$^3$/sec) | Standard Deviation | Relative Error |
|---|---|---|---|
| v7-200n47g No celldata | 2.70832E+05 | 1.25695E+03 | 0.00464 |
| v7-200n47g celldata | 3.00914E+05 | 2.07321E+03 | 0.00689 |
| MCNP CE nlib=70c | 3.04779E+05 | 2.01154E+03 | 0.0066 |

- CE and celldata results statistically the same
- No celldata results ~10% low
- In most cases, the use of only bonami appears to be adequate (instead of bonami plus centrm)

```
=mavric parm=(bonami)
exercise 1: neutron howitzer to activate gold foil
v7-200n47g
…
read celldata
  multiregion spherical left_bdy=reflected right_bdy=vacuum end
            1            5
            4       7.4995
            3       7.5005
            0           10
            2           30
      end zone
end celldata
…
end
```

# Not covered in training class

- Using pre-existing files
  - Forward, adjoint fluxes
  - Importance maps, mesh sources
- Plot block
  - 2D Plots
- Volume block
  - Calculate volumes




- Standard biasing
  - Region/energy weight windows, path length stretching, etc.

# Not covered in training class

- MAVRIC utilities
  - Mesh tally files *.3dmap (19)
  - Denovo flux files *.dff  (15)
  - TORT *.varscl Files from SCALE 6.1 (12)
  - Other (8) mesh sources, file displays, MCNP WWINP
- Advanced features
  - CADIS with beam sources
  - Importance maps with directional information
  - Univ. of Michigan methods for global VR
  - Using MAVRIC as an interface to the Denovo $S_N$ code
    - Forward or adjoint deterministic calculations

# Not covered in training class

- "Poor man's parallel"
  - Run one Denovo (it is serial only in SCALE)
  - Run many ($i = 1..I$) Monte Carlos
    - Each starting with *.adjoint.dff
    - Each with a different random number seed
  - Combine mesh tallies with MAVRIC utilities
  - Combine region and point detector tallies using
    - Each MC simulated $N_i$ histories to get $\bar{x}_i$ with uncertainty $\sigma_i$
    - Combine using
      - Total histories: $N = \sum N_i$
      - Average: $\bar{x} = \frac{1}{N}\sum N_i \bar{x}_i$
      - Uncertainty: $\sigma^2 = \frac{1}{N}\left[\frac{1}{N}\sum\left(N_i^2\sigma_i^2 + N_i\bar{x}_i^2\right) - \bar{x}^2\right]$

# Future additions to Monaco/MAVRIC

- Energy deposition tally
  - KERMA
- Thick-target bremsstrahlung (TTB)
  - Enabled by default
- Photonuclear reactions
  - Nuclear data with extended energy ranges
- Enhancements for MAVRIC-Shift
  - CAAS support via fissions source from CSAS-Shift HDF5 file
  - Source angular distributions

# Where to get help

- SCALE manual (https://scale-manual.ornl.gov)
  - Theory
  - Detailed input formats
  - Examples
- SCALE website (http://scale.ornl.gov/)
  - Newsletters
  - Electronic users' group
    - https://groups.google.com/forum/#!forum/scale-users-group
  - Updates about future training
  - Publications
  - SCALE Users' Group Annual Workshop – annual gathering at ORNL
- SCALE Help
  - scaleHelp@ornl.gov