OAK RIDGE National Laboratory

Nuclide Inventories with ORIGAMI for Criticality Safety Models

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Practical application of ORIGAMI to generate nuclide inventory data for use in criticality safety models

- **Goal**: determine **bias and bias uncertainty for burnup credit criticality safety** that are associated with isotopic depletion validation.
- The nuclide compositions uncertainty is propagated to bias and uncertainty in k_{eff} of reference models.
- Cask criticality models served as reference models under NUREG-7108[1] (2012) and NUREG-7109[2] (2012).
- Each reference model has unique assembly-average burnup and enrichment.
- The cask consists of 32 W 17x17 fuel assemblies. Each fuel element is discretized into 18 axial zones with different burnups.
- Using TRITON to compute the nuclides inventory is computationally expensive.
- TRITON is used to generate burnup-dependent ORIGEN libraries for the fuel assembly and then ORIGAMI uses these libraries to rapidly generate nuclides inventory for any enrichment/burnup combination.
- This approach is more efficient since TRITON depletion calculation takes **hours** whereas ORIGAMI takes **seconds**.

[1] G. Radulescu , I. Gauld , G. Ilas, and J. Wagner, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses–isotopic Composition Predictions," NUREG/CR-7108, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research (2012).
[2] J. M. Scaglione , D. E. Mueller , J. C. Wagner , W. J. Marshall ,'' An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (k_{eff}) Predictions ", NUREG/CR-7109, U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research (2012).

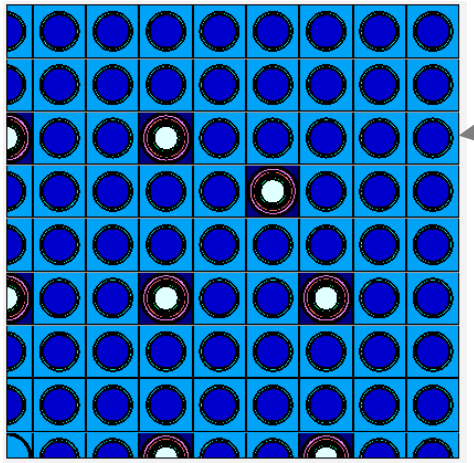
Overview of the workflow

- Generate ORIGEN reactor libraries at different assembly enrichments.
- Each library includes cross sections at different burnups

- Rapidly calculate inventory at different burnups/enrichments

- Use the resulting nuclide inventory in CSAS model to calculate k_{eff}

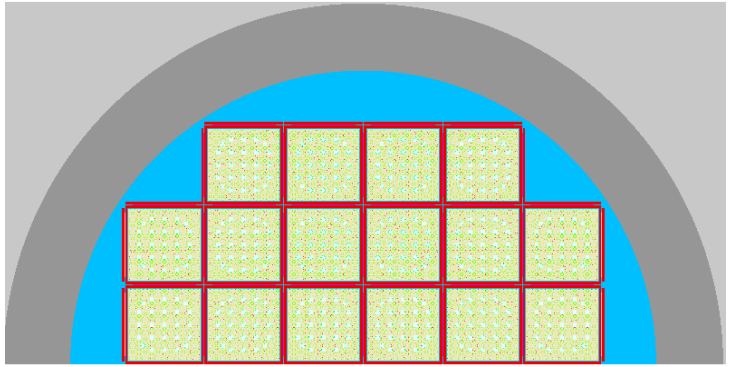
TRITON → ORIGAMI → CSAS



TRITON assembly model

```
=origami
  title='PWR cask'
  options{ft71=all, stdcomp=yes,fdens=10.5216}
  libs=[ "w17x17_waba" ]
  fuelcomp{
    mix(1){ stdcomp(fuel){
              base=uo2 iso[92235=6.0 92238=94.0]
            }
    }
  }
  hist[
    cycle{ power=60 burn=500 nlib=15}
    cycle{ down=100 }
    cycle{ down=100 }
  ]
end
```

Sample of ORIGAMI input

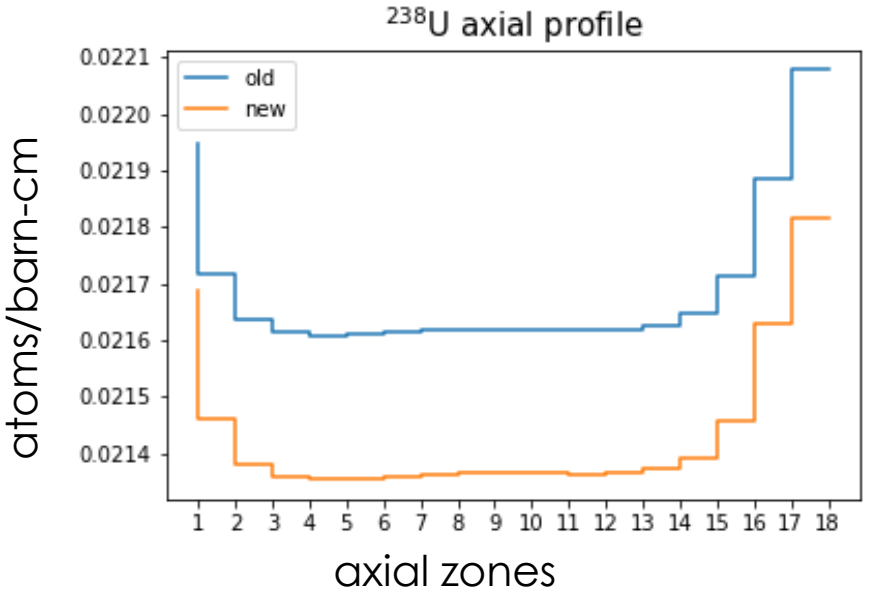


CSAS cask model

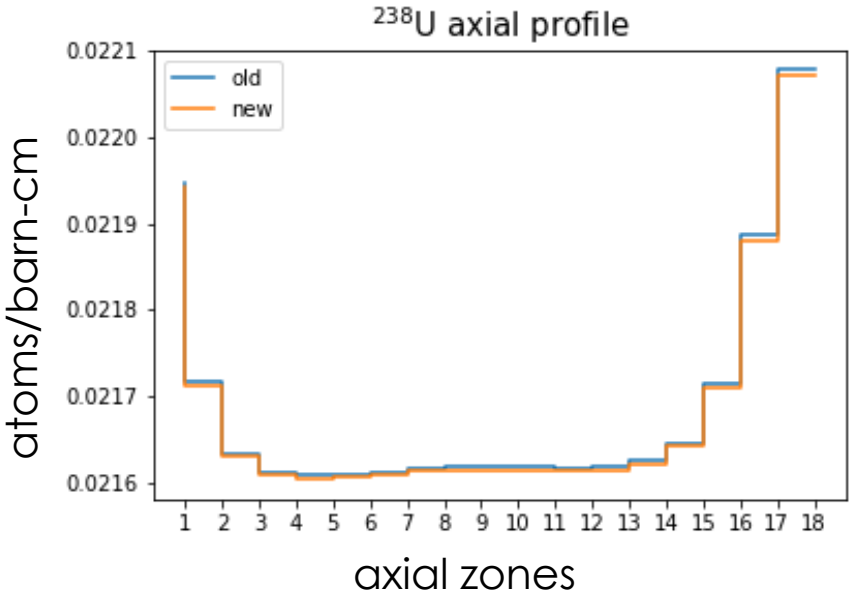
ORIGAMI tips1/3

- ***fdens*** must be specified if actual fuel density is different from the default density value in ORIGAMI (**10.4 g/cm^3**)
- Using wrong fuel density will result in an inaccurate isotopic composition and accordingly wrong k_{eff}

```
=origami
  title='PWR cask'
  options{ft71=all, stdcomp=yes,fdens=10.5216}
```



default fdens



correct fdens

ORIGAMI tips 2/3

nlibs: not too many, not too few

- ***nlibs***: number of ORIGEN library burnup-interpolations during the cycle.
- Few interpolation points might cause inaccurate results because of the error introduced by interpolation.
- Too many interpolation points could add unnecessary computational cost.
- Burnup step is recommended to be ~ 2 GWd/MTU.

```
  hist[
    cycle{ power=60 burn=500 nlib=15}
    cycle{ down=100 }
    cycle{ down=100 }
  ]
end
```

ORIGAMI tips 3/3

Format of output nuclides inventory in atom/barn-cm to be provided to CSAS

Option 1: use *stdcomp=yes*

- generates separate text file ***myInput_compBlock.txt***
- concentrations are given at the last time step
- the resulting file can be used directly in CSAS input.

```
=origami
  title='PWR cask'
  options{ft71=all, stdcomp=yes, fdens=10.5216}
```

```
    o-16      1001   0   4.6818E-02    293.0 end
    u-234     1001   0   1.0369E-08    293.0 end
    u-235     1001   0   3.8858E-04    293.0 end
    u-236     1001   0   2.1565E-05    293.0 end
    u-238     1001   0   2.2841E-02    293.0 end
    np-237    1001   0   9.6119E-07    293.0 end
    pu-238    1001   0   5.3095E-08    293.0 end
```

Option 2: use *OPUS*

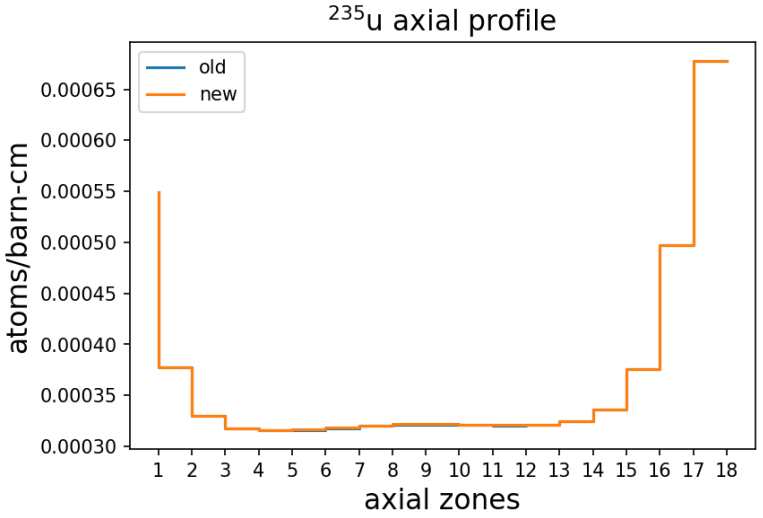
- generates separate text file ***myInput.plt***
- concentrations are given with lower precision

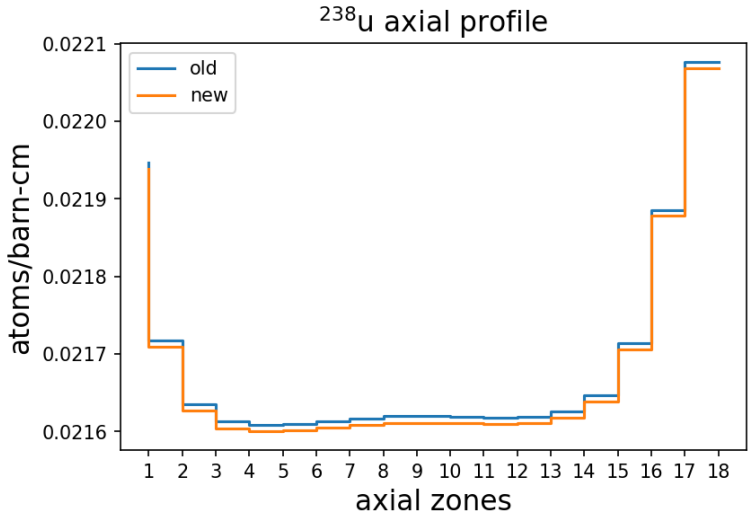
```
=opus
data="myInp.f71"
title="cask"
typarams=nuclides
nrank=22
symnuc=U234 U235 U236 U238  Np237 Pu238 Pu239 Pu240 Pu241
       Tc99 Ru101 Rh103 Ag109 Cs133 Nd143 Nd145  Sm147 Sm149 Sm150
        Sm151 Eu151 Sm152 Eu153 Gd155 o16 end
sort=no
units=ATOM
end
```

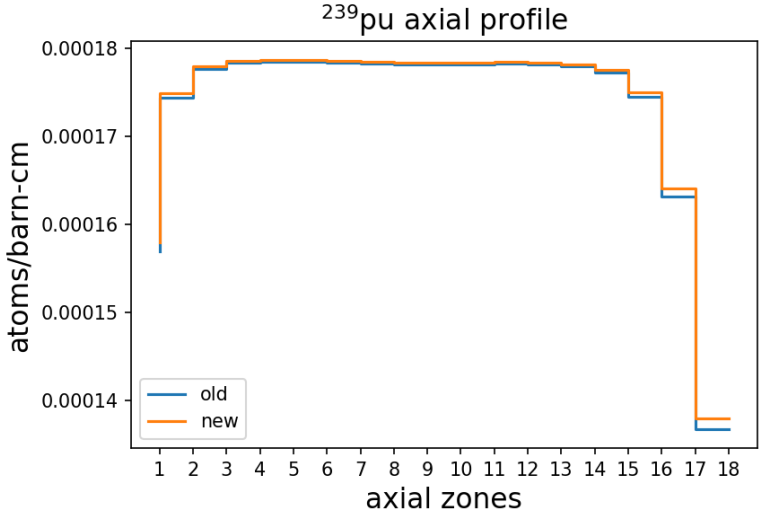
```
cask
time (d)
at/bcm
nuclide
49 31
                  0.000e+00 3.262e+01 6.524e+01 9.785e+01
             u234 0.000e+00 8.956e-04 1.751e-03 2.567e-03
             u235 1.767e+02 1.704e+02 1.645e+02 1.587e+02
             u236 0.000e+00 1.314e+00 2.570e+00 3.772e+00
             u238 2.355e+03 2.353e+03 2.350e+03 2.347e+03
```

Verify consistency of ORIGAMI-based methodology for generating axial fuel composition to an old methodology

new – based on ORIGAMI with ORIGEN reactor libraries generated with SCALE 6.1.3/ 238 gr ENDF/B-VII.0
old – based on STARBUCS with ORIGEN reactor libraries generated with SCALE 6.1.3/238 gr ENDF/B-VII.0







Burnup=40 GWd/MTU, Enrichment=4.63506 %