# Tools for perturbation theory in MCNP6

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# The MCNP PERT and KPERT cards quantify the linear reactivity response due to perturbations

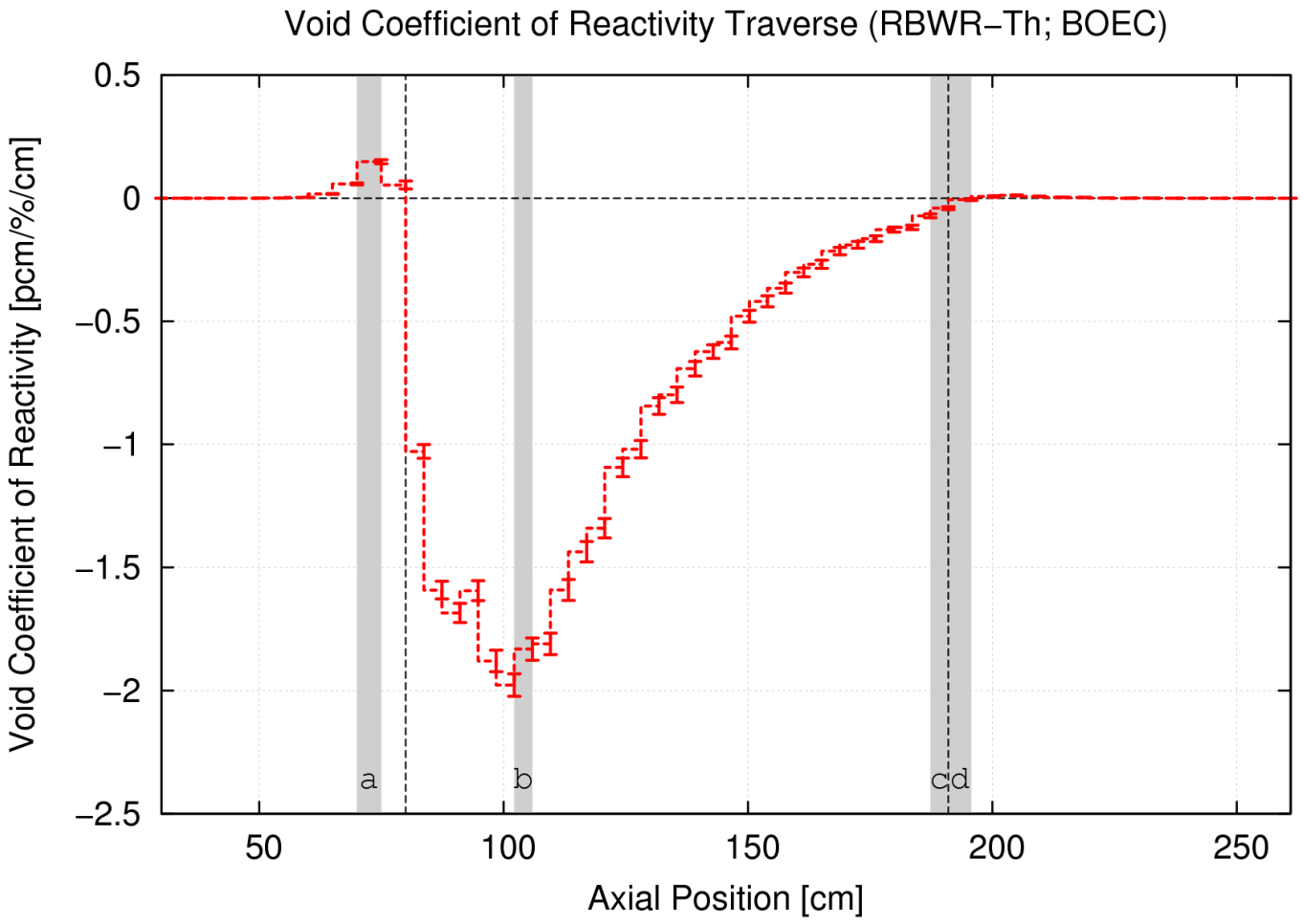
- **You may perturb a cell's …**
  - **Material density (e.g., voiding)**
  - **Material number (e.g., composition, data library, temperature)**

- **Effects can be binned by …**
  - **Nuclear reaction type**
  - **Energy bin**
  - **Isotope (KPERT only)**

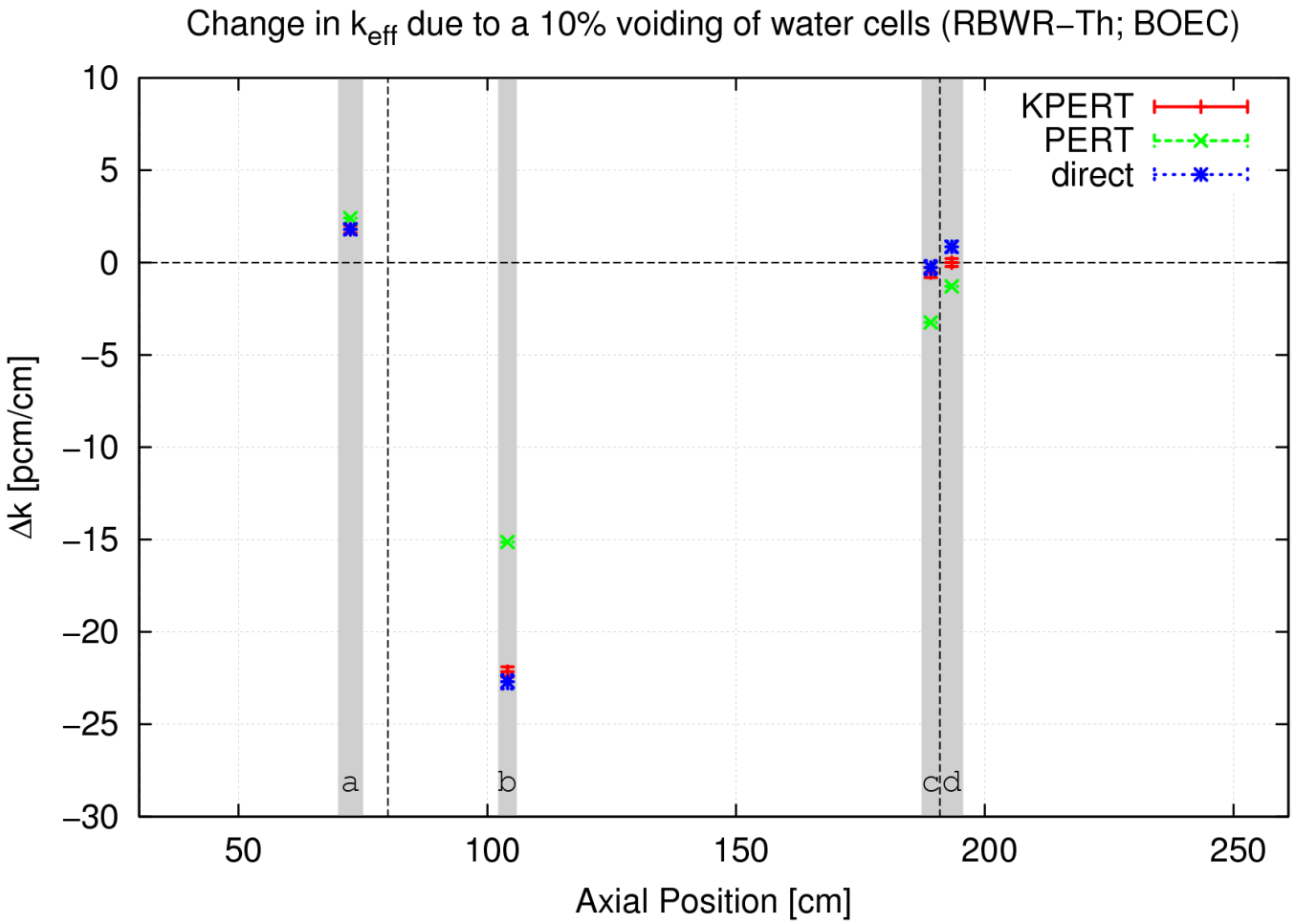
- **Individual perturbations can be combined**

- **Many independent perturbations can be considered at once with a single neutron transport calculation!**

# The MCNP KPERT cards can efficiently estimate local void coefficients of reactivity



# PERT is faster than KPERT, but less accurate



# Material density perturbation w/ PERT and KPERT: $\rho_m \times = 1.1$

```
 Godiva  Solid Bare HEU sphere  HEU-MET-FAST-001
1 1 4.7984e-02 -1 imp:n=1
2 0            +1 imp:n=0

1 so 8.7407

kcode 5000 1 50 250
sdef 0 0 0
m1 92234.70c +4.9184e-04 92235.70c +4.4994e-02
   92238.70c +2.4984e-03
kpert1:n cell=1 rho=5.27824e-2
pert2:n  cell=1 rho=5.27824e-2 method=2
```



Note: always use **`method=2`** for PERT cards

# Data library perturbation w/ energy binning: ENDF/B-VII.0→ENDF/B-VI.8

```
 Godiva  Solid Bare HEU sphere  HEU-MET-FAST-001
1 1 4.7984e-02 -1 imp:n=1
2 0            +1 imp:n=0

1 so 8.7407

kcode 5000 1 50 250
sdef 0 0 0
m1 92234.70c +4.9184e-04 92235.70c +4.4994e-02
   92238.70c +2.4984e-03
m2 92234.62c +4.9184e-04 92235.62c +4.4994e-02
   92238.62c +2.4984e-03
kpert1:n cell=1 mat=2 erg=0 1e-6 0.1 20
         iso=92234 92235 92238
```

# Isotopic composition perturbation w/ reaction binning: $N_{Li\text{-}7} \times = 0.9$

```
...
1 1 8.345641e-2 +1 imp:n=1
...

m1    3006.72c 0.0000202 3007.72c 1.9999790
      4009.72c 1         9019.72c 4
m2    3006.72c 0.0000202 3007.72c 1.7999820
      4009.72c 1         9019.72c 4
kpert1:n cell=1 mat=2 rho=8.11568e-2 rxn=1 2 102
```



Note: a new material and kpert card are required for every isotope perturbed and considered

# KSEN estimates $k_{eff}$ sensitivity coefficients

- **Sensitivities quantify the relative linear reactivity response due to a relative change in some parameter**

$$S_{k,p} \equiv \frac{\partial k}{\partial p}\frac{p}{k} \approx \frac{\delta k}{k}\frac{p}{\delta p}$$

- **Parameters can be the (space independent) …**
  - **abundance of an isotope**
  - **cross-section for an isotope for a given reaction at a given energy**

- **Sensitivity coefficients …**
  - **are typically estimated as distributions over space, energy, isotope, region, direction;**
  - **can be collapsed and used to derive PERT and KPERT estimates**

# Sensitivity of $k_{eff}$ to number densities and nuclear data

```
 Godiva  Solid Bare HEU sphere  HEU-MET-FAST-001
1 1 4.7984e-02 -1 imp:n=1
2 0            +1 imp:n=0

1 so 8.7407

kcode 5000 1 50 250
sdef 0 0 0
m1 92234.70c +4.9184e-04 92235.70c +4.4994e-02
   92238.70c +2.4984e-03
ksen1:n xs iso=92234.70c 92235.70c 92238.70c
        rxn=1 2 4 18 102 erg=0 1e-6 1e-3 1 10 20
```

# Conclusions

- **PERT and KPERT are for perturbations (few Δ's); KSEN is for sensitivity (many Δ's)**

- **With some creativity, perturbation theory can do useful things:**
  - **Assess coefficients of reactivity**
  - **Assess the impact of (some) modeling assumptions**
  - **Optimize position of control worth**
  - **Propagate nuclear data uncertainties (KSEN)**
  - **Quantify the impact of impurities upon reactivity (KSEN)**

- **KPERT and KSEN are only available in MCNP6**

- **You should switch to MCNP6**



For documentation, see LA-CP-13-00634, pp. 3-243—3-256