Business from technology

On Doppler-broadening Rejection Correction (DBRC)

Tuomas Viitanen

Serpent User Group Meeting, Berkeley, USA

November 6–8, 2013

Elastic scattering kinetics in MC

- When an elastic scattering occurs, the velocity and direction of the scattered neutron depends on the velocity of the target nucleus.
- When $S(\alpha, \beta)$ tables are available, the secondary particle distributions can be sampled straight from them (bound-atom scattering)
- When the tables are not available, the velocities are actually sampled.
  - At relatively low energies so called free gas treatment is used.
  - Above a threshold energy (400 kT) the target is assumed to be stationary.

Free Gas Treatment

- Distribution traditionally used for sampling target velocities (Solbrig)

$$P(V_{\mathrm{t}}, \mu) = \frac{v_{\mathrm{r}}}{2v} f_{\mathrm{MB}}(V_{\mathrm{t}}, T) \quad (1)$$

includes an assumption

$$\frac{\sigma_{\mathrm{s}}(v_{\mathrm{r}}, 0)}{\sigma_{\mathrm{s}}(v, T)} \approx 0 \quad (2)$$

- Correct distribution:

$$P(V_{\mathrm{t}}, \mu) = \frac{\sigma_{\mathrm{s}}(v_{\mathrm{r}}, 0)}{\sigma_{\mathrm{s}}(v, T)} \frac{v_{\mathrm{r}}}{2v} f_{\mathrm{MB}}(V_{\mathrm{t}}, T) \quad (3)$$

DBRC

- Doppler-broadening Rejection Correction is a methdod for taking into account the effect of varying cross sections on the target velocity distribution.
- The velocity distribution becomes correct if velocities are sampled from distribution (Rothenstein, Dagan, Becker)

$$P(V_{\mathrm{t}}, \mu) = \frac{\sigma_{\mathrm{s}}(v_{\mathrm{r}}, 0)}{\sigma_{\mathrm{s,maj}}(v)} \frac{v_{\mathrm{r}}}{2v} f_{\mathrm{MB}}(V_{\mathrm{t}}, T) \tag{4}$$

where $\sigma_{\mathrm{s,maj}}(v)$ is the maximum zero Kelvin scattering xs within the range of thermal motion around v.

Effects of DBRC

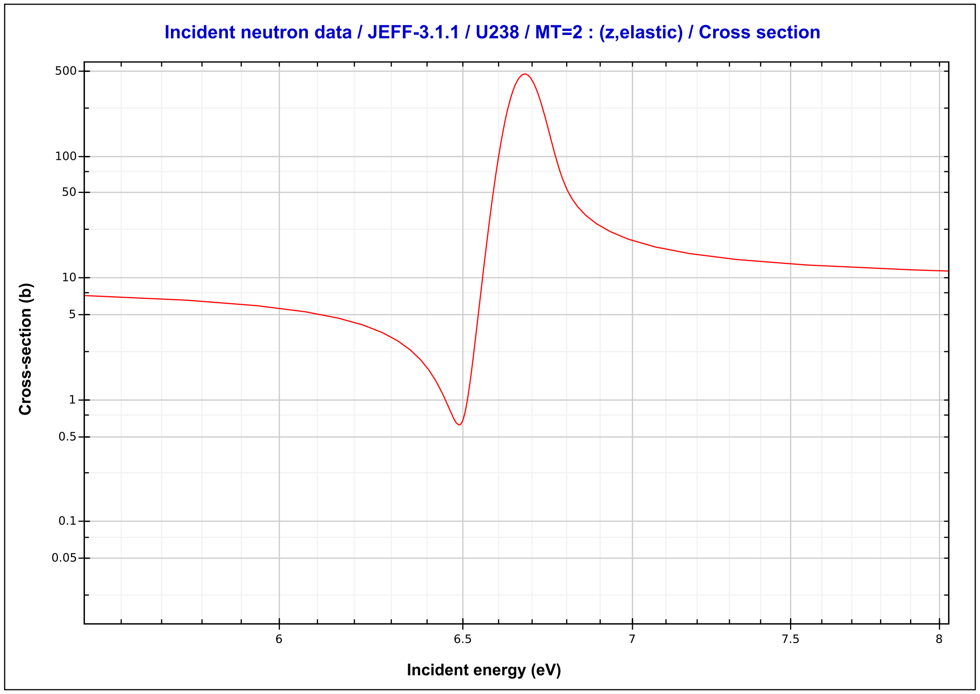


Figure 1: Elastic scattering xs of $^{238}\mathrm{U}$ xs near the lowest resonance.

$$P(V_{\mathrm{t}},\mu)=\frac{\sigma_{\mathrm{s}}(v_{\mathrm{r}},0)}{\sigma_{\mathrm{s,maj}}(v)}\frac{v_{\mathrm{r}}}{2v}f_{\mathrm{MB}}(V_{\mathrm{t}},T) \quad (5)$$

DBRC in Serpent

```
set dbrc 0.4E-6 2.1E-4 92238.00c
```

- Minimum and maximum energy for DBRC
- List of 0 K cross sections for DBRC nuclides.

Effect on results: fresh fuel

Table 1: **Eigenvalues with and without DBRC for U-238.**

System	without DBRC	with DBRC	Δk_{eff} (pcm)
PWR @ HFP	1.28917 $\pm$ 18 pcm	1.28735 $\pm$ 18	182
HTGR @ “HFP”	1.20995 $\pm$ 27 pcm	1.20093 $\pm$ 27	902

Effect on results: burnup calculation (1/2)

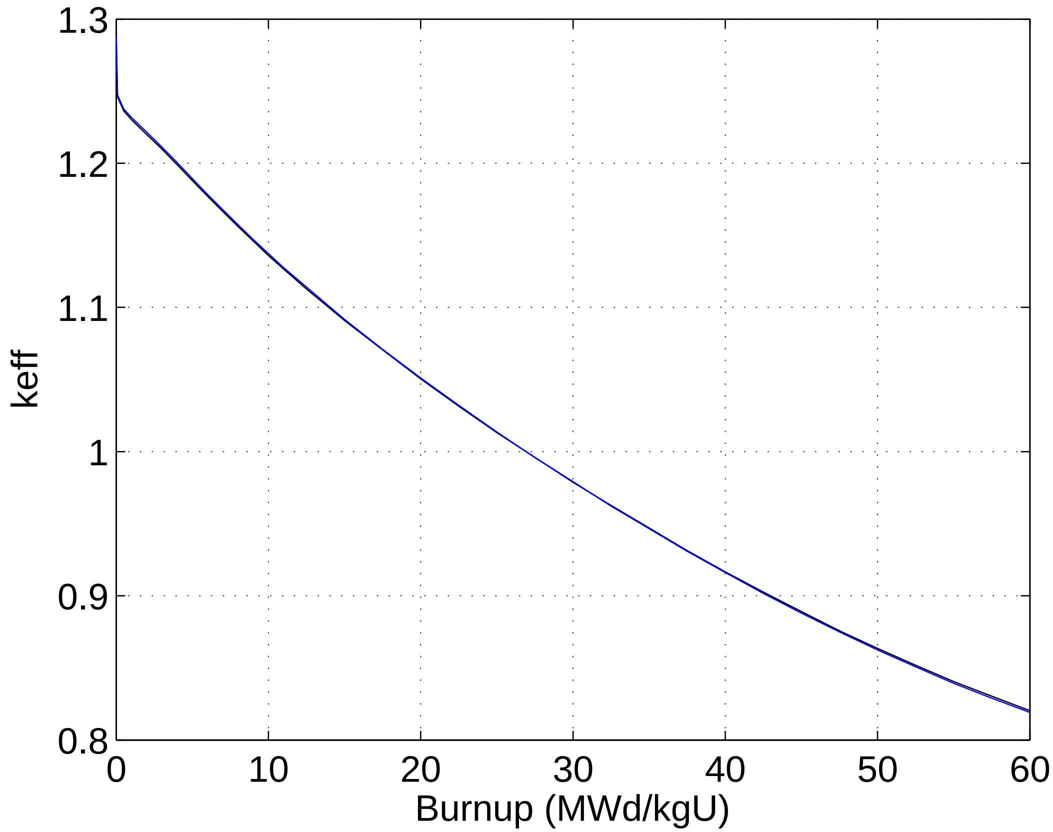


Figure 2:

Effect on results: burnup calculation (2/2)

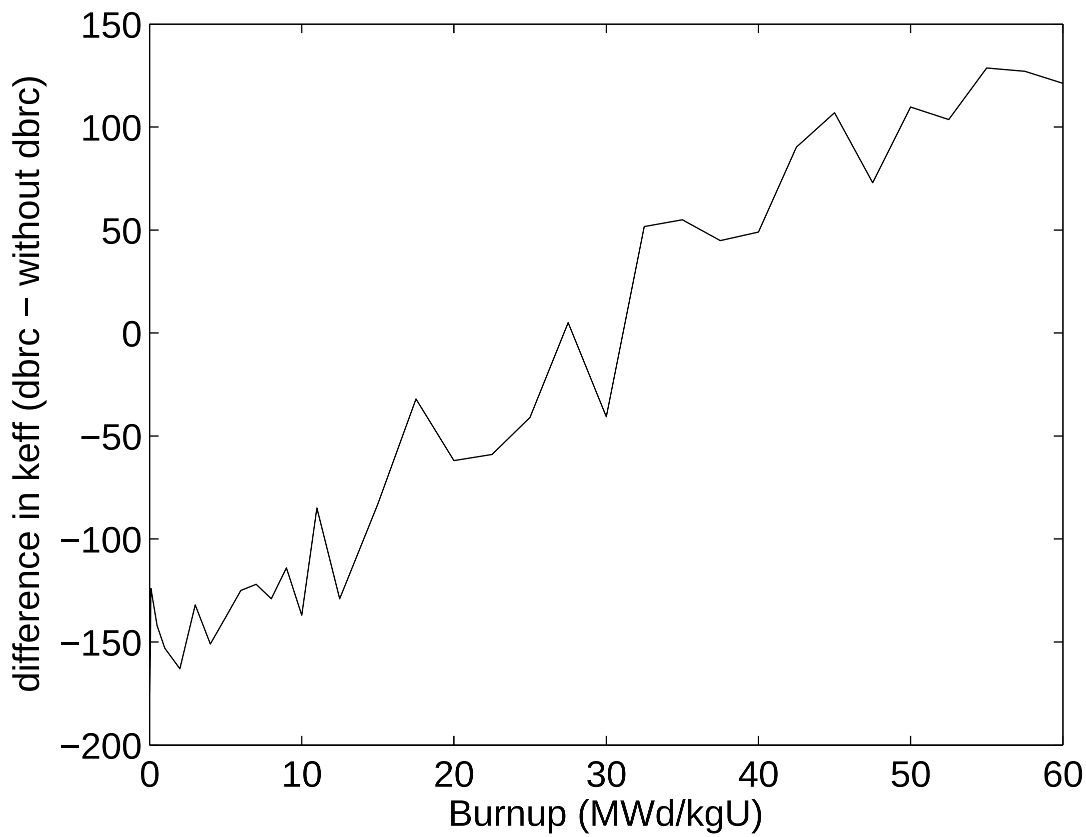
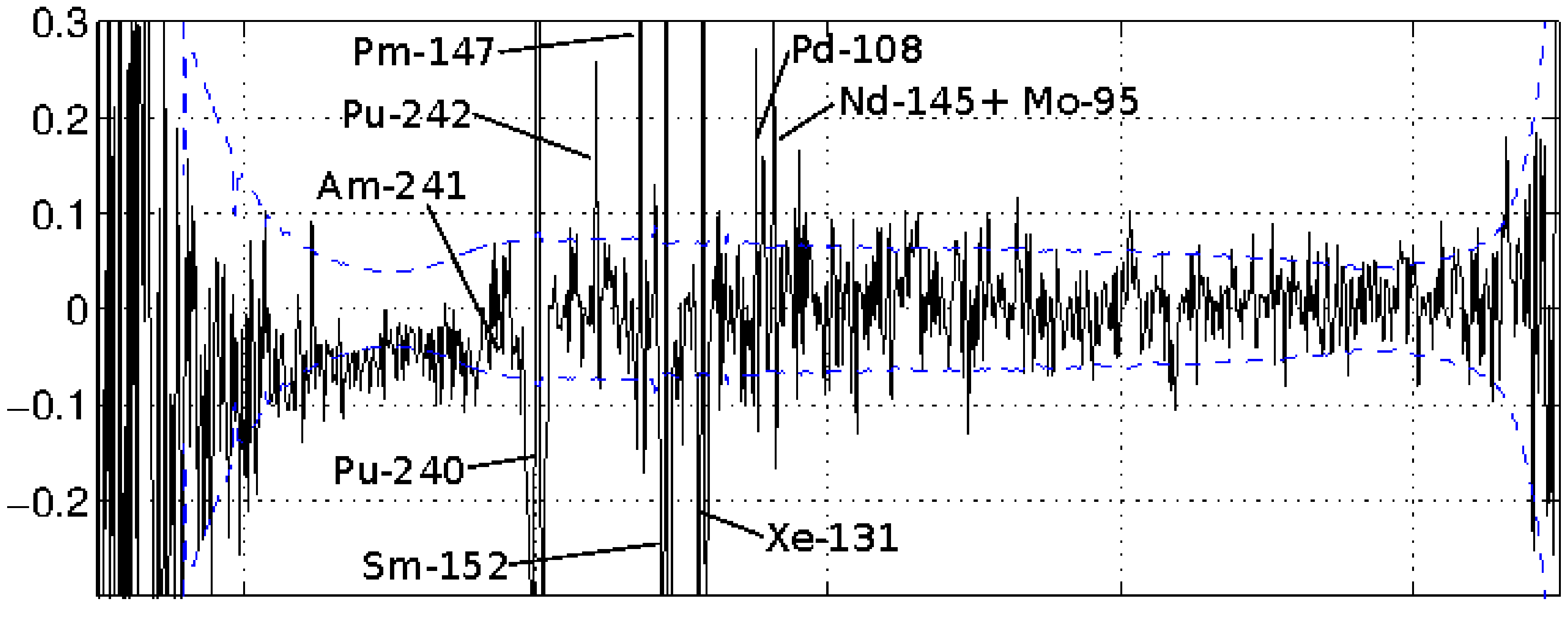


Figure 3:

What nuclides to include?

- $^{238}\mathrm{U}$ is the most significant, but...



Conclusion

- The standard way of calculating elastic scattering kinetics is **wrong**
- The error significantly affects the resonance absorption rates, which leads to
  - Too high k_{eff} at BOL
  - Too small $^{239}\mathrm{Pu}$ concentrations at EOL when calculating burnup.
- The error can be corrected using DBRC.
  - $^{238}\mathrm{U}$ is the most significant.
  - If interested in accurate actinide concentrations, add at least $^{240}\mathrm{Pu}$.