Uncertainty Propagation with Fast Monte Carlo Techniques

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(Monte Carlo vs. Deterministic S/U...)

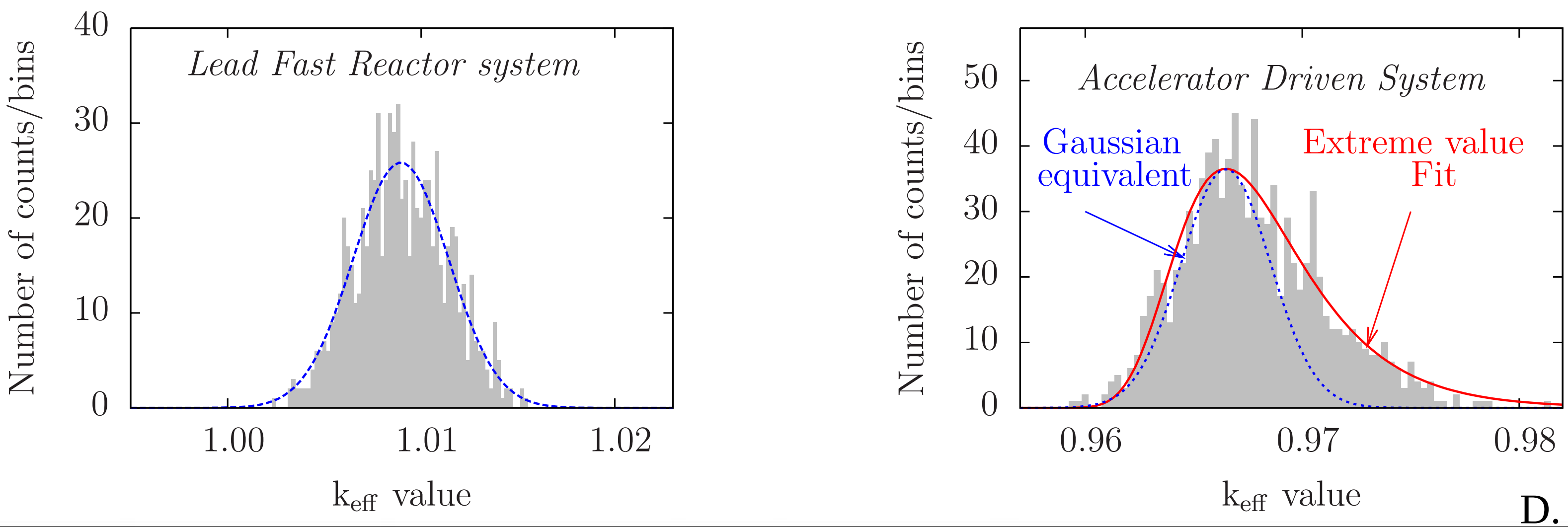
2008: Total Monte Carlo (TMC)

Control of nuclear data (TALYS system)
+ processing (NJOY)
+ system simulation (MCNP/ERANOS/CASMO...)

1000 times

For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the *n* calculations, *n* different k_{eff} values are obtained.

$$\sigma^2_{total} = \sigma^2_{statistics} + \sigma^2_{nuclear\ data}$$



Advantages of the TMC method

- many presentations at ND,
- computer time (not human time),
- Successfully applied (criticality, shielding, reactor, burn-up...)
- Most simple path (no additional processing, no covariance required),
- Other variants: AREVA (NUDUNA), GRS (XSUSA), CIEMAT (ACAB), PSI (NUSS), CNRS Grenoble..., based on covariance files,
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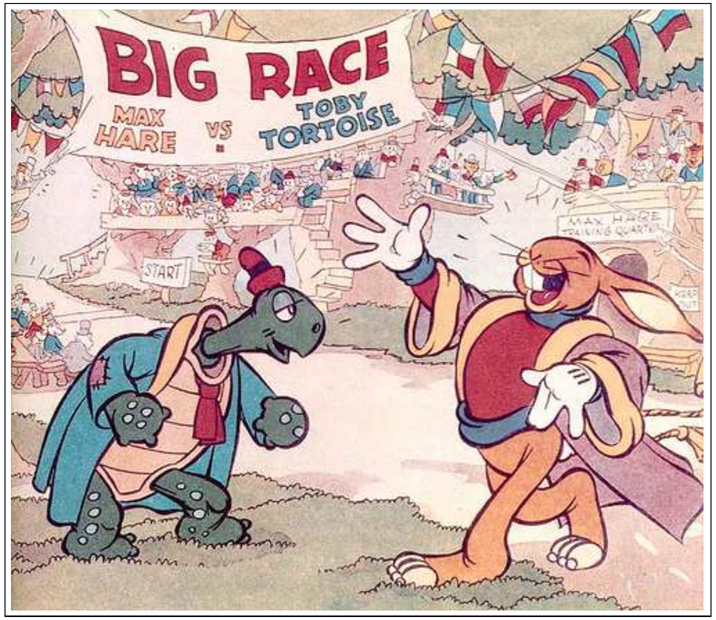
But can TMC overtake (at least compete with) S/U methods ?



Drawbacks of the TMC method

In TMC:

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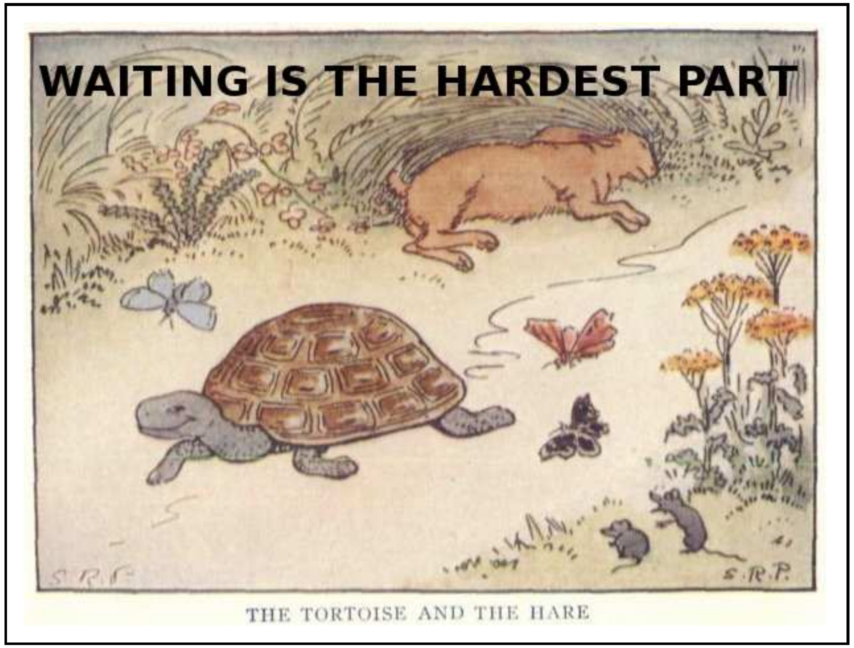

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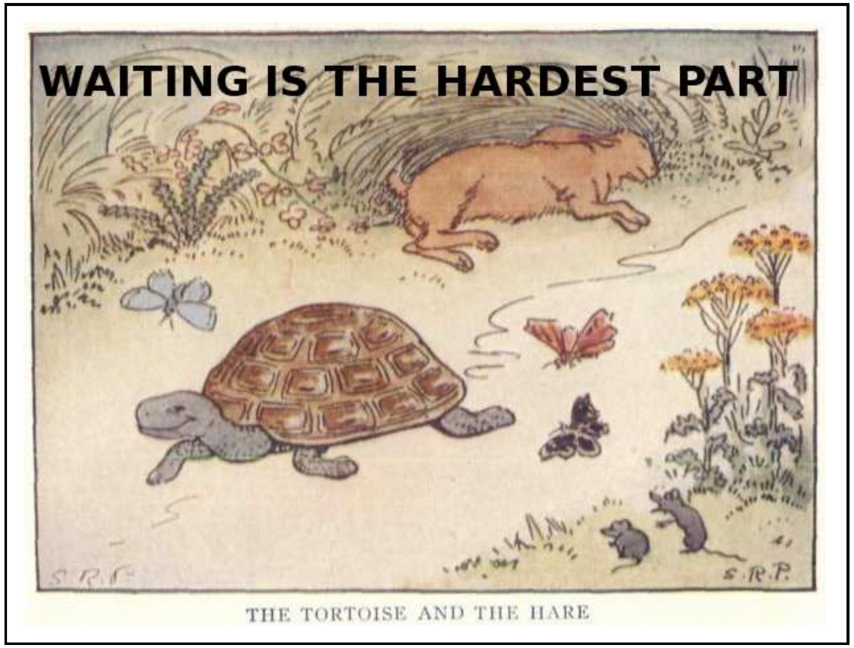

There is a solution with Monte Carlo codes:
(in fact 2 solutions)

- fast GRS method,
- and fast TMC.

2012: fast GRS method

First presented in PHYSOR-2012 by W. Zwermann *et al.*. It takes advantage of conditional expectations:

If two output variables $k^{(1)}$ and $k^{(2)}$ are identically distributed and conditionally independent given the vector of nuclear data input then

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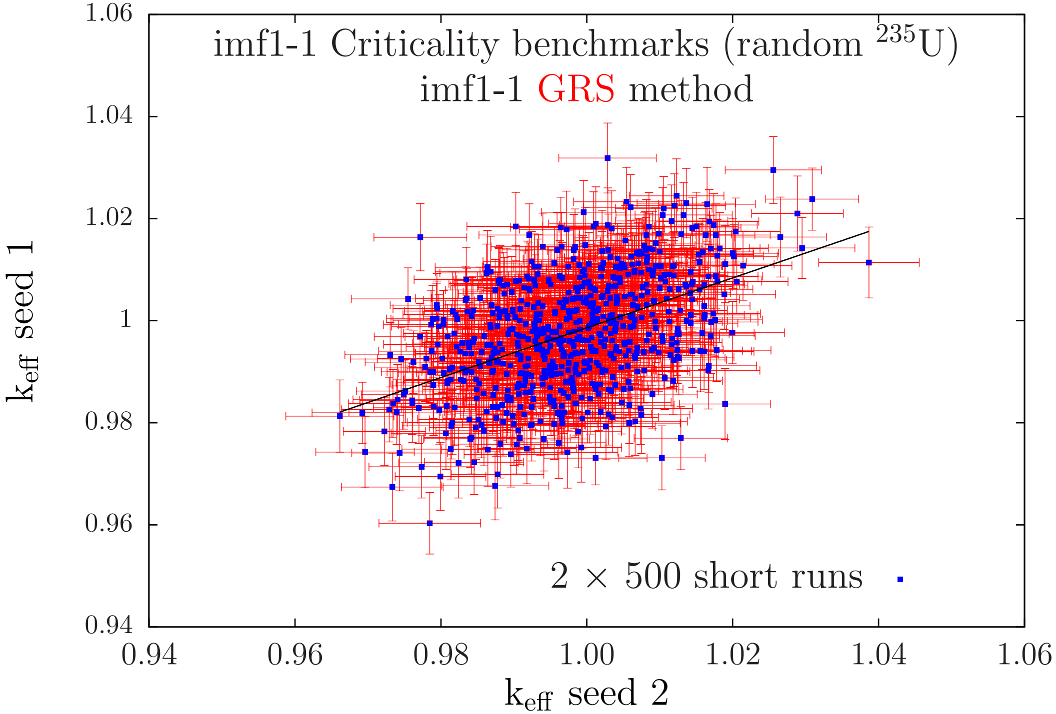
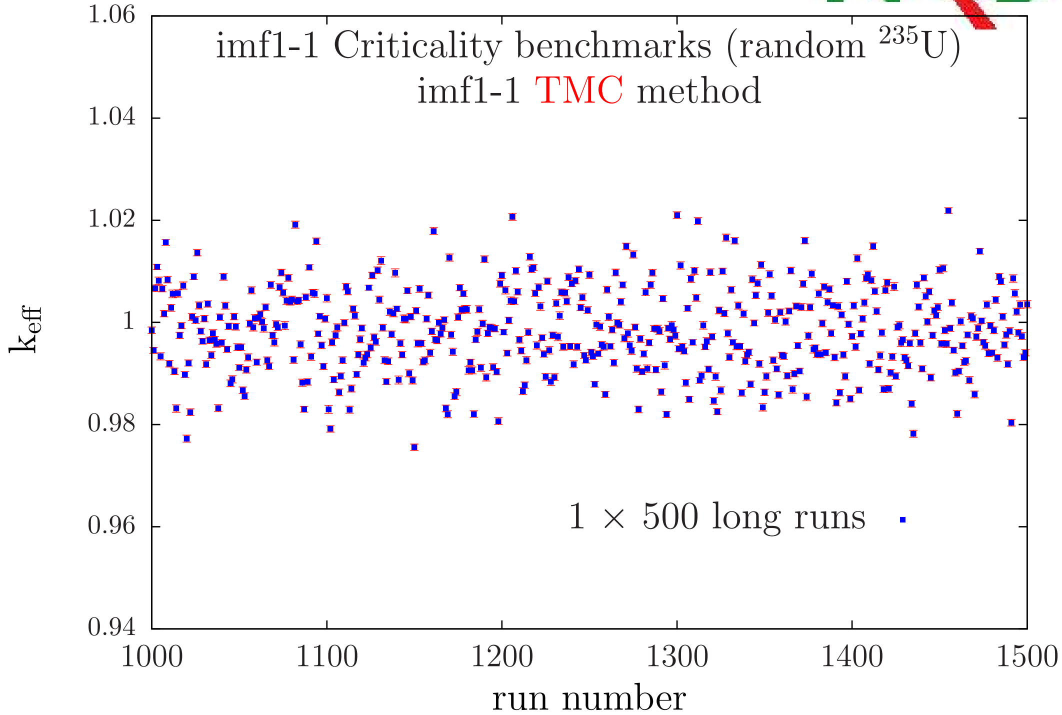
In practice:

1. perform $i = 1..500$ MCNP short calculations with random nuclear data and a fixed seed $s_1 \Longrightarrow k_{\text{eff}}^{(1)}(i)$
2. repeat for $j = 1..500$, same random nuclear data but fixed seed $s_2 \Longrightarrow k_{\text{eff}}^{(2)}(j)$

There is no necessity to have small $\sigma_{\text{statistics}}$!!
each run can be (very) short

fast GRS method





$$\sigma_{\mathrm{nucl.data}} = \sqrt{\mathrm{cov}(\vec{k_1}, \vec{k_2})} = \sqrt{\mathrm{corr}(\vec{k_1}, \vec{k_2}) \times \sigma_1 \sigma_2}$$
$$= \sqrt{0.48 \times 0.0110 \times 0.0112}$$
$$= 770 \text{ pcm}$$

$$\sigma_{\mathrm{nucl.data}} = \sqrt{\sigma_1^2 - \sigma_{\mathrm{stat}}^2}$$
$$= \sqrt{0.0805^2 - 0.00067^2}$$
$$= 802 \text{ pcm}$$

2×500 "*short*" runs $\sim 2 \times$ "*long*" run in time

2013: fast TMC method...

If a single calculation takes m histories (σ_{stat} small enough), then repeat it n times with m/n histories, random nuclear data and random seeds.
$\sigma^2_{\text{total}} = \sigma^2_{\text{statistics}} + \sigma^2_{\text{nuclear data}}$ still holds.

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$$\begin{cases} \sigma^2_{total} & = \frac{1}{n-1}\sum_{i=1}^{n}\left(k_i - \bar{k}\right)^2 \\ \sigma^2_{statistics} & = \frac{1}{n}\sum_{i=1}^{n}\sigma^2_i \end{cases}$$

The fast methods

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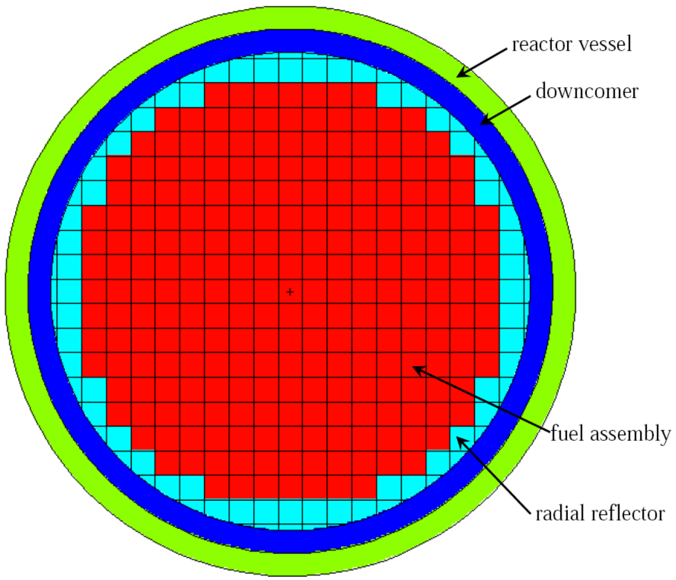
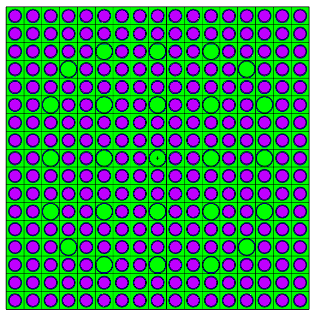
MCNP model: 241 fuel assemblies, with 264 fuel pins each





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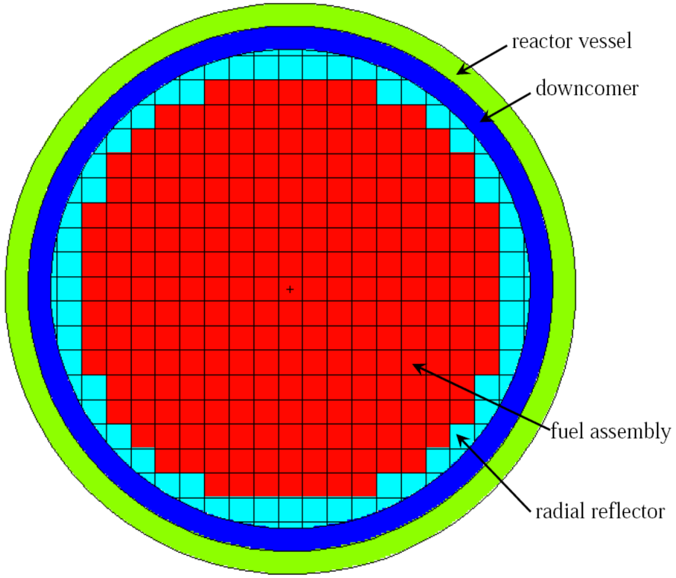

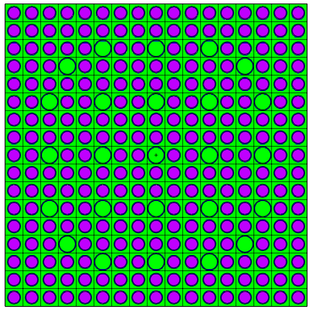

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Uncertainty on generated local pin power (tally f7) due to ^{235}U, ^{238}U, ^{239}Pu and H in H_2O thermal scattering in each cell ?

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1 normal calculation without nuclear data uncertainty takes $n = 2 \times 10^{11}$ histories ($\sigma_{\text{statistics}} = 0.25$ % at the center, 500 weeks on 1 cpu)

$\Longrightarrow$ TMC: 500 random runs of $n = 2 \times 10^{11}$ histories (500 weeks for each)

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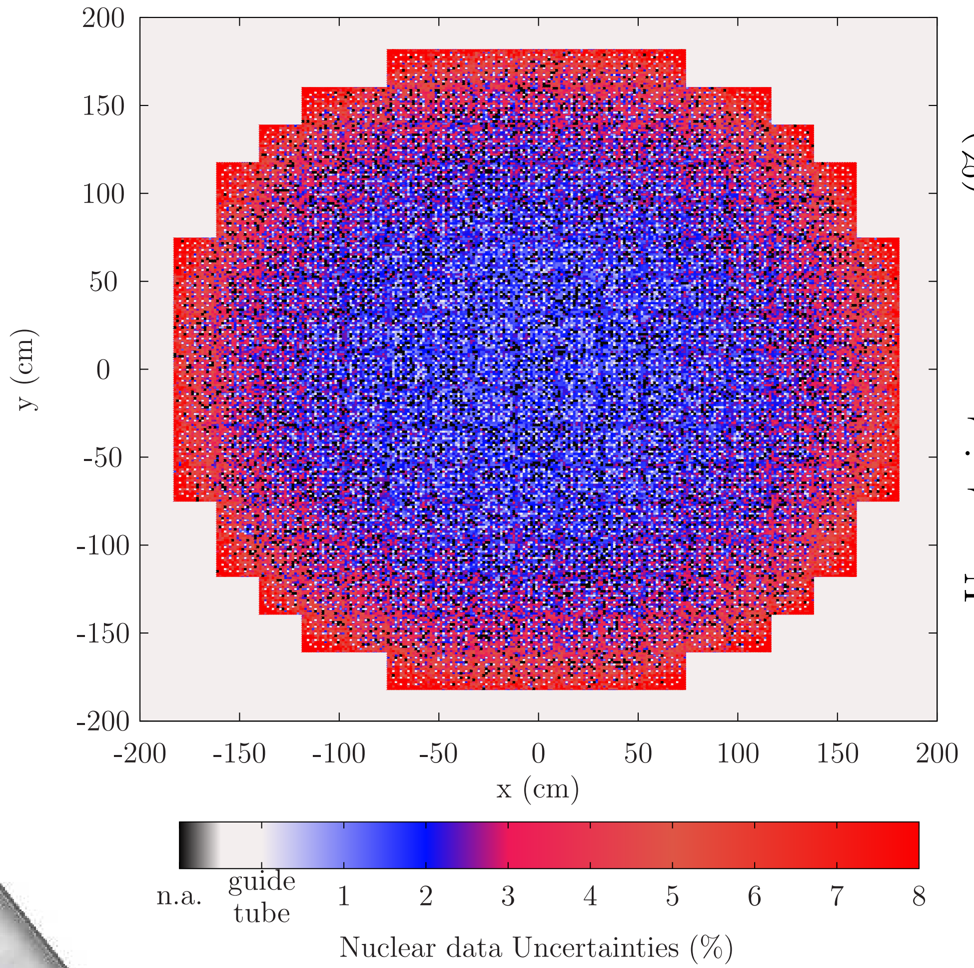

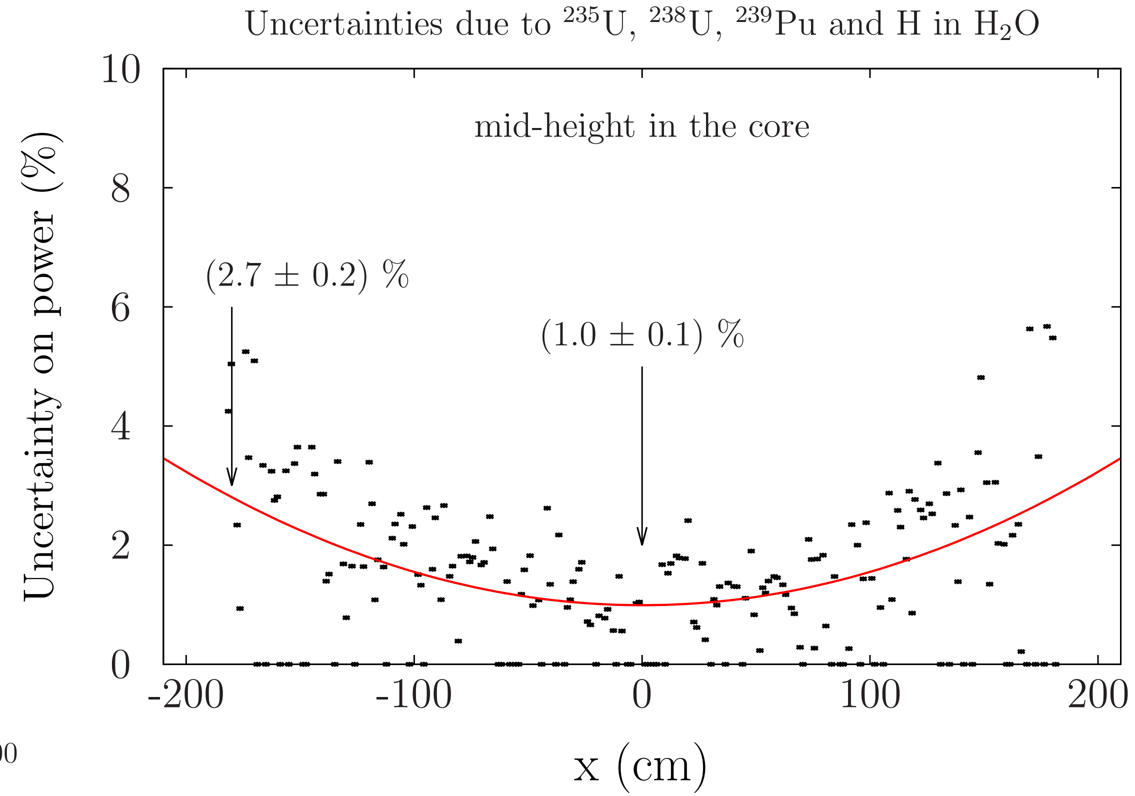

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fast TMC and GRS methods:
If we can do a calculation once, we can also get nuclear data uncertainties in twice the time (or less).