Petter Helgesson, Henrik Sjöstrand: *Treating defects in nuclear reaction models to improve material damage parameters and their uncertainties*

Nuclear Data underpin all of Nuclear Science and Technology!
Nuclear data: how is it done?

Nuclear physics experiments

Nuclear physics model codes

Requirements (sensitivity analysis)

Nuclear data evaluation

End-user applications

Uncertainties! Quality Assurance: Reproducibility
Sampling based evaluation and uncertainty propagation: TMC
TMC – Måbil - goals

• Improve methods to include both differential and integral experimental data in a rigorous way

• Assess uncertainties in aging and fuel parameters, e.g., flux, DPA, and gas production
Primary Radiation Damage: from nuclear reaction to points defects

• Going all the way from nuclear reactions to material defects requires physics on many levels.

From IAEA technical meeting (F4-TM-43223):

“...demonstrated that significant uncertainties remain regarding both the development of nuclear data and the use of these data by the materials modeling community to determine the primary damage state obtained in irradiated materials.”

Goal: Build competence and knowledge in the interface nuclear data / material science
• revisit the NRT standard for its improving by the inspection of recoil spectra and by the evaluation of uncertainties;
• check evaluated gas production cross sections and make recommendations.
Results: Ni-59

Completed: Accepted for JEFF 3.3 T4 and NDS
# Different Techniques for Nuclear Data evaluation

<table>
<thead>
<tr>
<th>Observable domain</th>
<th>Parameter domain</th>
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<tbody>
<tr>
<td><strong>GLS</strong></td>
<td><strong>GLS-P</strong></td>
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<tr>
<td>- Generalized Least Squares</td>
<td></td>
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<tr>
<td>- Standard regression allowing for prior and correlated data</td>
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<tr>
<td>- Observable and exp. data ~ $N(\cdot)$</td>
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</tr>
<tr>
<td>- GLS in parameter domain for linearization found using Levenberg-Marquardt</td>
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<tr>
<td>- Parameters and exp. data ~ $N(\cdot)$</td>
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<table>
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<th>Monte Carlo</th>
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<tbody>
<tr>
<td><strong>UMC-G</strong></td>
<td><strong>UMC-B = TMC</strong></td>
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<tr>
<td>- Unified Monte Carlo – “Garage”</td>
<td></td>
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<tr>
<td>- (Any) distr. assumed for prior observable and exp. data</td>
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<tr>
<td>- UMC – “Breakfast”</td>
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</tbody>
</table>
P. Helgesson et al., *Assessment of Novel Techniques for Nuclear Data Evaluation*, 16th International Symposium of Reactor Dosimetry

- Systematic comparison of evaluation methods
  - Model shape ≈ PFNS
- Main difference between observable and parameter domain
- Model based: smaller evaluation bias but poorer uncertainty estimates
  - More sensitive to model defects
    - Gaussian Processes promising
Gaussian Processes

\[ Y = f(x; \beta) + \epsilon_m(x) + \epsilon(x) \]

- Methods taken from machine learning
- \( \epsilon_m(x) \) determined by using the deviation between the model and experimental data
GP for Fission Yields

Fission yield measurements. Left: without GP. Right with GP.
Conclusion and outlook

• Ni-59, a unique evaluation in terms of co-variance. **Completed!**

• New evaluation methods have been developed and tests. **Completed!**

• Outlook: First results for iron using GP and GLS-P is available and will be presented during 2017.
Artikel i tidskrift (published)


Konferensbidrag


Övrigt


Helgesson P., Sjöstrand H., Rochman D., Koning A.; "Evaluation of the Ni-59 cross sections including thermal (n,\alpha), (n,p) and complete uncertainty information"; Permalink: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-313638; (2016)


Licentiatavhandling, sammanläggning

Helgesson P.; "Experimental data and Total Monte Carlo : Towards justified, transparent and complete nuclear data uncertainties"; Publisher: Uppsala universitet; Permalink: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-265330; (2015)
Any questions?

Fission is the mission.

Slogan: