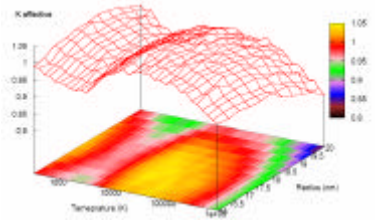
Sellafield Ltd

EHS&Q

Development of Run-Time Doppler Broadening for MONK and MCBEND

Richard Neal

Date: 5th March 2008



Contents

Introduction

- MONK – Monte Carlo program
  - Nuclear criticality safety
  - Reactor physics analyses
- Geometry made from simple bodies & “holes”
- Hyper fine group and point energy data libraries
  - UKNDL, JEF(F), ENDF/B, JENDL
- 172 group data-gram library
- Superhistory powering

Introduction

- MCBEND – Monte Carlo program
  - Radiation transport
  - Neutron, gamma-ray and charged particle
- Geometry made from simple bodies & “holes”
- Hyper fine group and point energy data libraries
  - UKNDL, JEF(F), ENDF/B
- Robust variance reduction techniques
  - MAGIC – Importance map

Introduction

- NCD Agreement
  - Serco
  - Sellafield Limited
    - Work funded by the NDA
- Jointly managed by
  - Andrew J Cooper (Sellafield Ltd)
  - Pat Cowan (Serco)

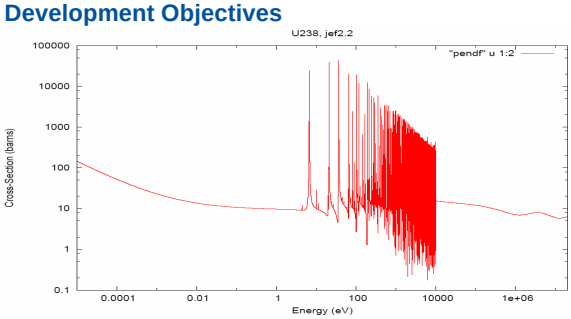
Introduction

- Safety Software team
  - Paul Hulse (Team Leader)
  - Robert Black
  - Simon Connolly
  - David Dewar
  - Richard Neal
  - Alex Perry
  - Keith Searson
  - Dave Bendall (Contractor)
  - Reg Brissenden (Contractor)
  - Ted Shuttleworth (Contractor)

Introduction

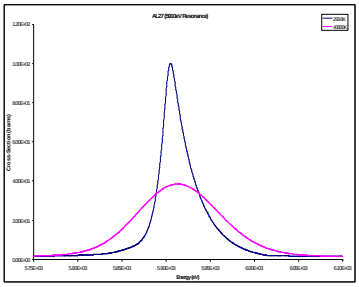
- Trimmed NURBS Surface Tracking
  - Must see presentation by Keith Searson
    - Tomorrow at 2 15pm
  - Import CAD models without remodelling
  - True model (no loss of geometric integrity)
- Decode (Test Harness)
  - Used as test bed for developments
  - Not a fully QA'd

Development Objectives



Development Objectives

- Doppler Broadening
  - Motion of the nuclei
  - Relative speed
  - Increasing width
  - U238 capture
  - Fission/Capture Ratio



Development Objectives

- Allow accurate modelling at elevated temperatures
  - No need to generate library at actual temperature
  - Minimise interpolation
  - Continuous temperature capability
    - Large or small changes in temperature can be modelled
- Integrate with thermal hydraulics code
- Other Applications

Development Objectives

- Avoid basic pitfalls
  - Efficiency
  - Accuracy
  - Storage requirements
- Technical areas of concern
  - Interpolation of thermal data
  - URR treatment in MONK

Method

- Doppler Broadening
  - Gaussian Quadrature
- Thermal Data
  - Interpolation of cross-sections
- Unresolved Resonance Region
  - Interpolation of subgroup data, or
  - generation of GENEX ladders

Method – Doppler Broadening

- Gaussian Quadrature
  - Gauss-Hermite

$$\int_{-\infty}^{\infty} e^{-x^2} f(x)dx = \sum_{i}^{N} w_i f(x_i)$$

  - Effective Cross-Section

$$s_{eff}(E) = \frac{m}{2E}\sqrt{\frac{1}{p}}\int_{\Delta} e^{-x^2}[Z_2 + Z_1]dx$$

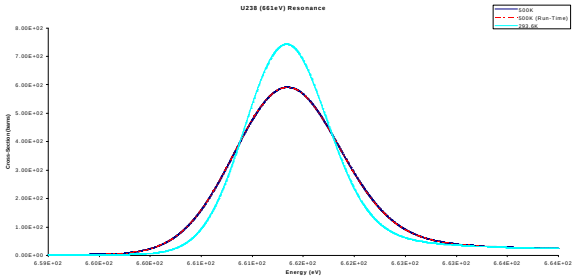
Method – Gaussian Quadrature

- No more equations!!
- Very efficient method
- Very accurate
  - Limited increases from base temperature
  - Have stepped “base” temperature data

Capability

- Continuous Temperature Calculations
  - Room Temperature
  - One million Kelvin
- Time Penalty
  - Depends on number of Abscissa values
  - ~3-4 times slower (10 Abscissa values)
  - No penalty at “base” temperatures

Performance



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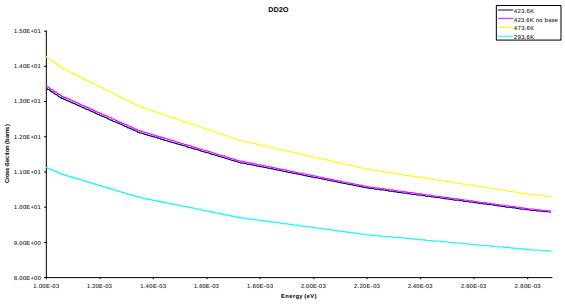

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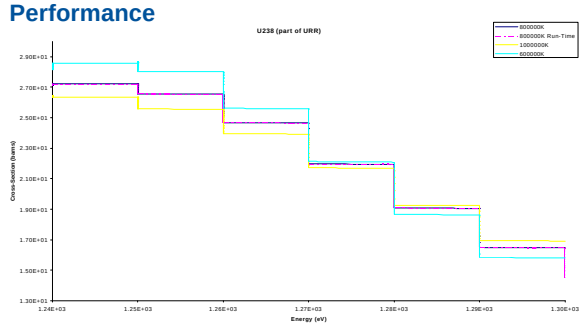

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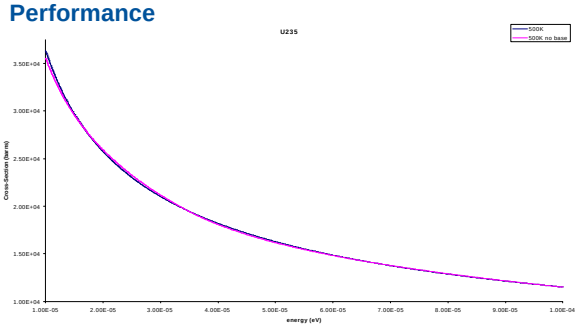

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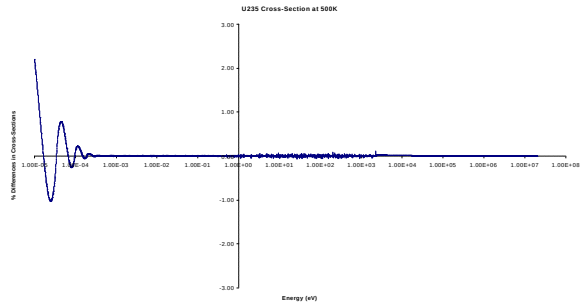

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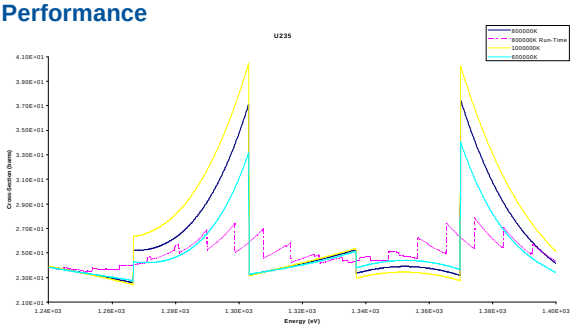

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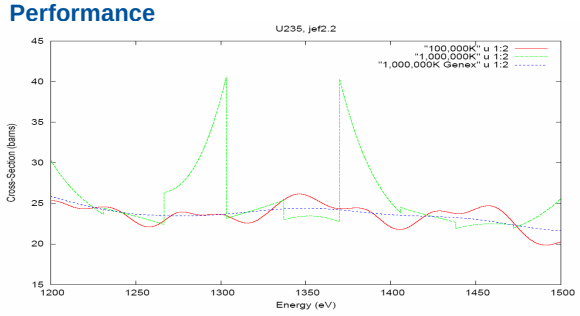

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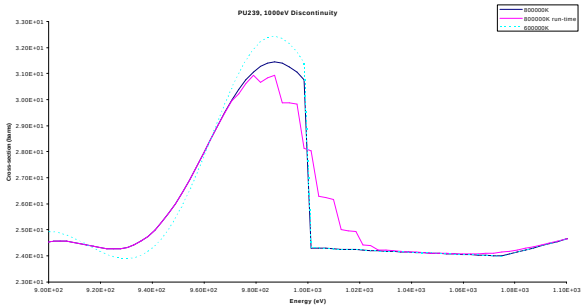

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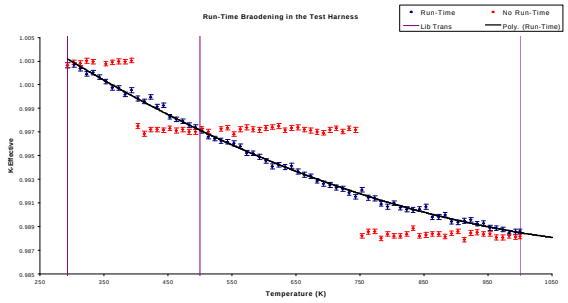

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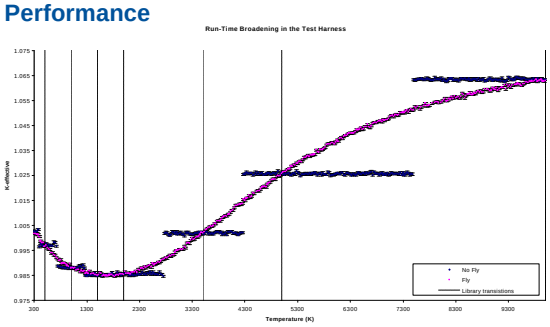

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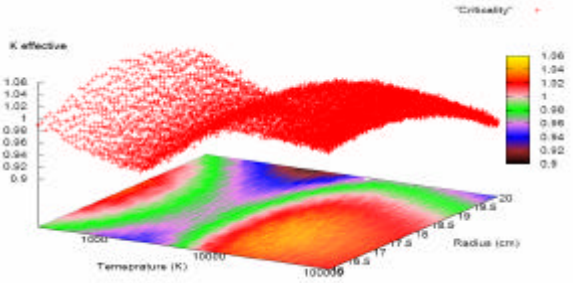

Further Work

- Small differences at low energies
- Problems where sharp spikes exist in data (e.g. ^{57}Fe)
- Problems with discontinuities
- Problems in NJOY generated data at very high temperatures
- Integration of method into MONK and MCBEND
- Validation

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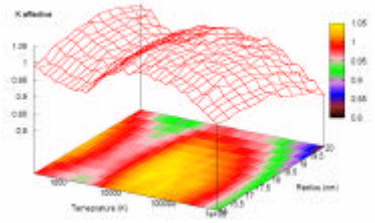

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