Studsvik

SNF decay data library Update and evaluation

Teo Simeonov and Charles Wemple

ND2016

11-16 September 2016

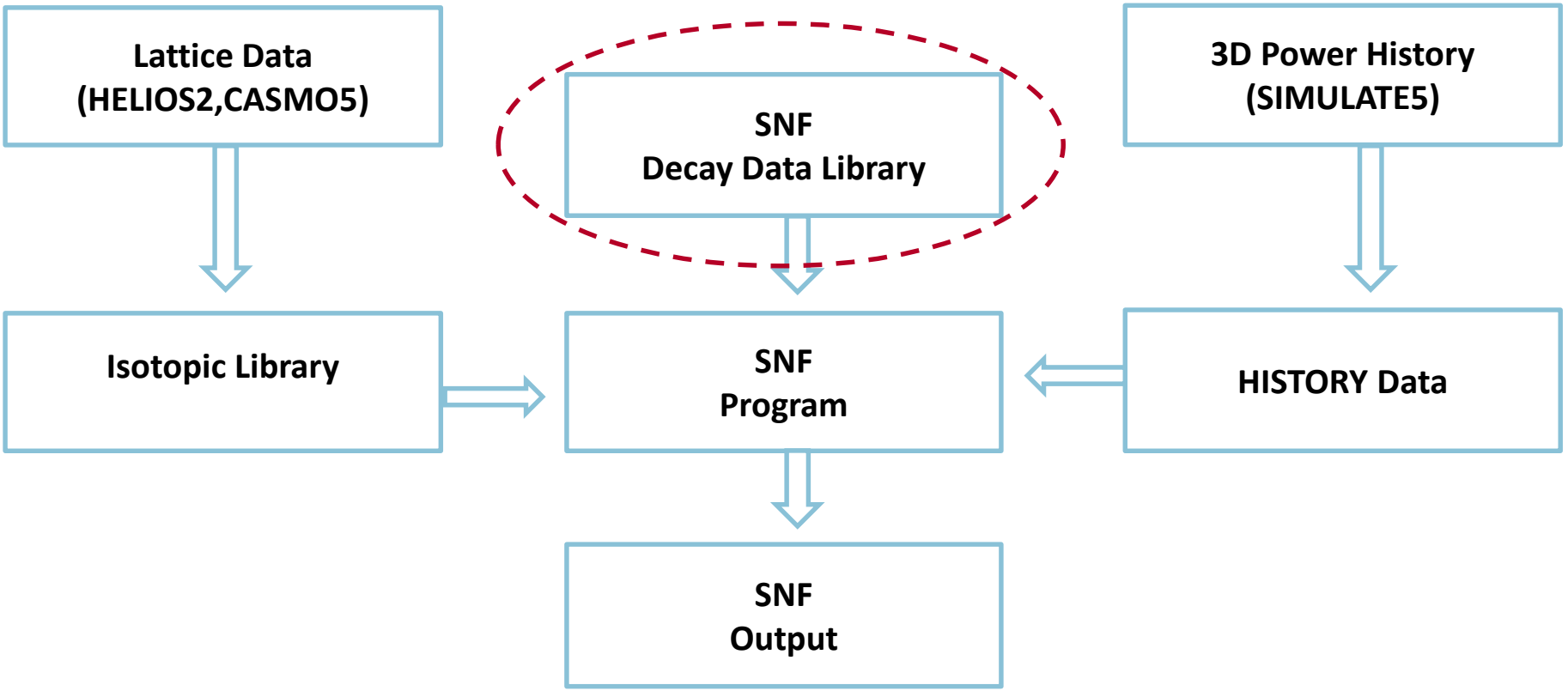
Bruges, Belgium

Contents

- The project
- Results
- Sources and Processing
- Consistency Checks and Validation
- Summary and Future Work

The project – Decay Data Library Update

- Studsvik System for Spent Nuclear Fuel Analyses



Data and Sources

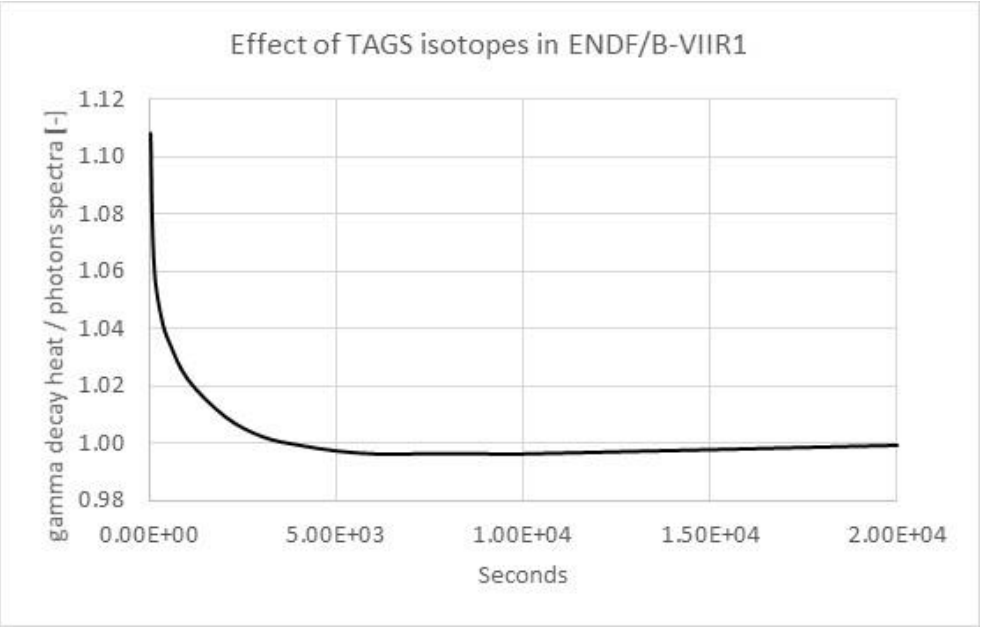
- Decay data from publicly available evaluations for all available isotopes
- Basic decay data (ENDF/B-VIIR1)
- Emission spectra
  - Spontaneous fission neutrons (ENDF)
  - Neutrons from alpha-n reactions (ENDF, TENDL, ASTAR)
  - Alphas (ENDF)
  - Betas and positrons (ENDF)
  - Photons
    - Gammas (ENDF)
    - X-ray (ENDF)
    - Bremsstrahlung (ENDF, ESTAR)
- Fission product yields (ENDF)
- Uncertainties (ENDF)

Status

- A repeatable procedure for decay data updates is established
- Data consistency was found to be generally satisfactory
- Next steps
  - Apply the updated decay data library to Studsvik system for spent fuel analyses
  - SNF code validation suite
  - Release for production

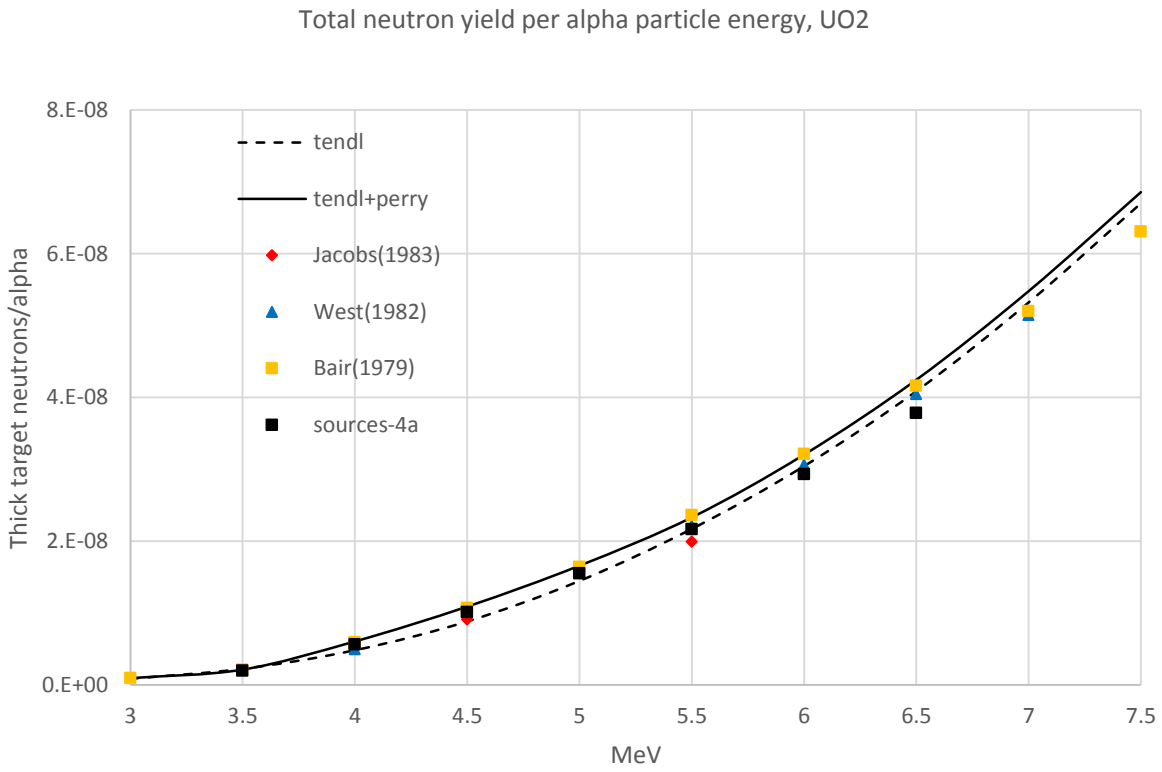
Consistency checks

- Mainly a book-keeping exercise, involving cross checks with other nuclear data evaluations and/or revisions. Almost all encountered direct differences were within the stated uncertainties or were deemed improvements in the evaluated data
- For example, recoverable energy from electromagnetic radiation: a discrepancy is observed between the evaluated mean energy and the energy computed by integration of calculated photon spectra for decay times up to $2x10^4$ s and the reason was found in ENDF corrections related to the so called “pandemonium” effect (TAGS isotopes)
- 48 isotopes with deviations greater than 0.5%
- 4 with integrated energy greater than the mean
  - ^{145}Ba, ^{142}La, ^{155}Nd, and ^{155}Pm
  - ~0.3% difference at $2x10^3$ s



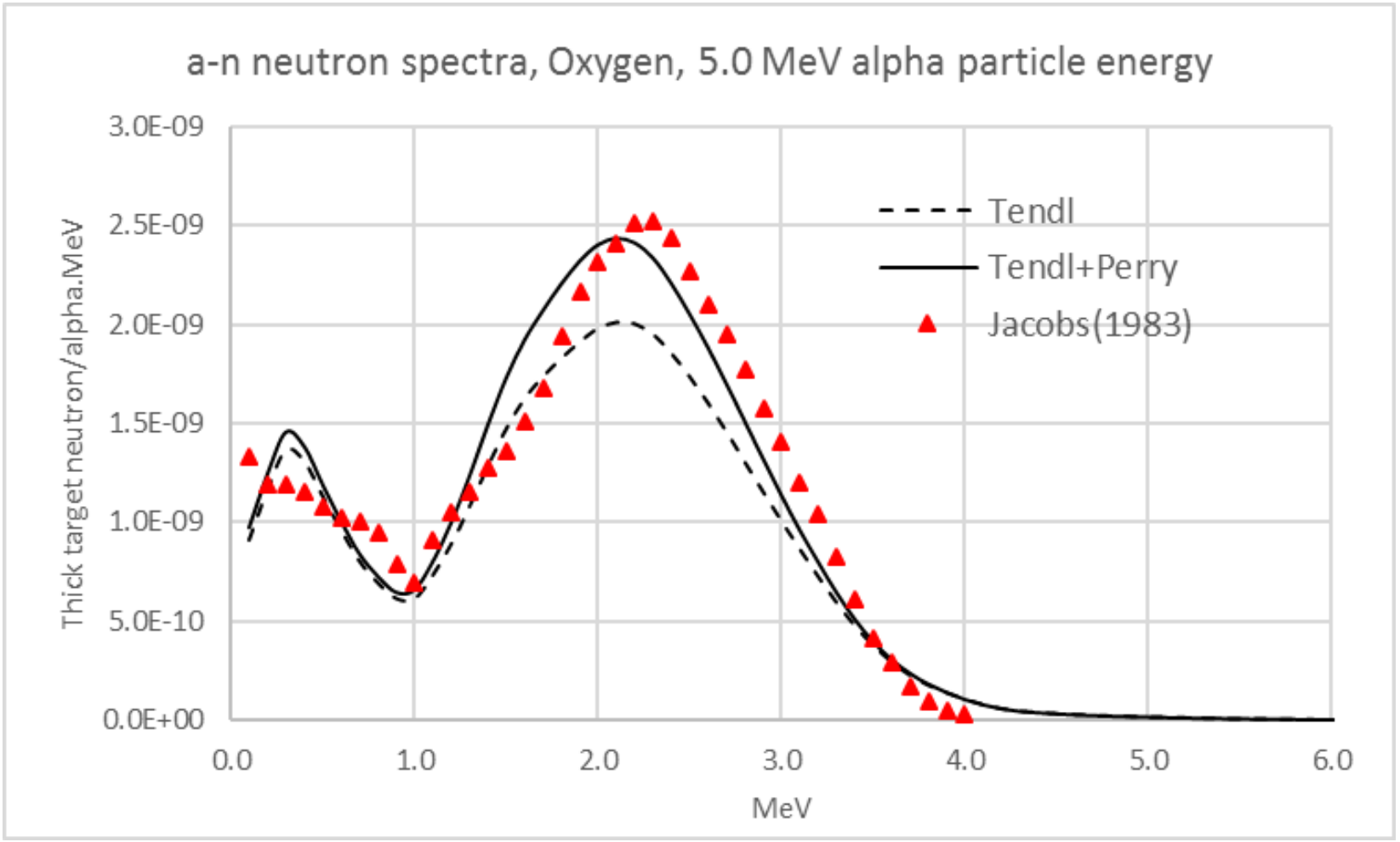
Neutron yields from alpha-n reactions

- (α,n) data for 43 isotopes processed from TENDL-2014 by NJOY-2012
- Low energy (α,n) cross sections for ^{17}O and ^{18}O complemented by Perry and Wilson data
- Alpha particle stopping powers for elements and compounds derived from ASTAR
- Example for UO2
  - The TENDL data are in good agreement to measurements



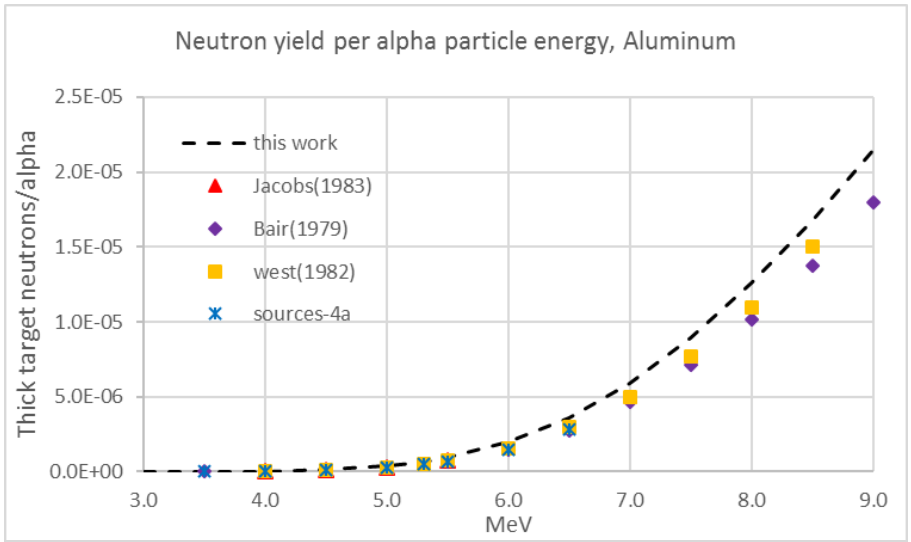
Neutron spectra from alpha-n reactions

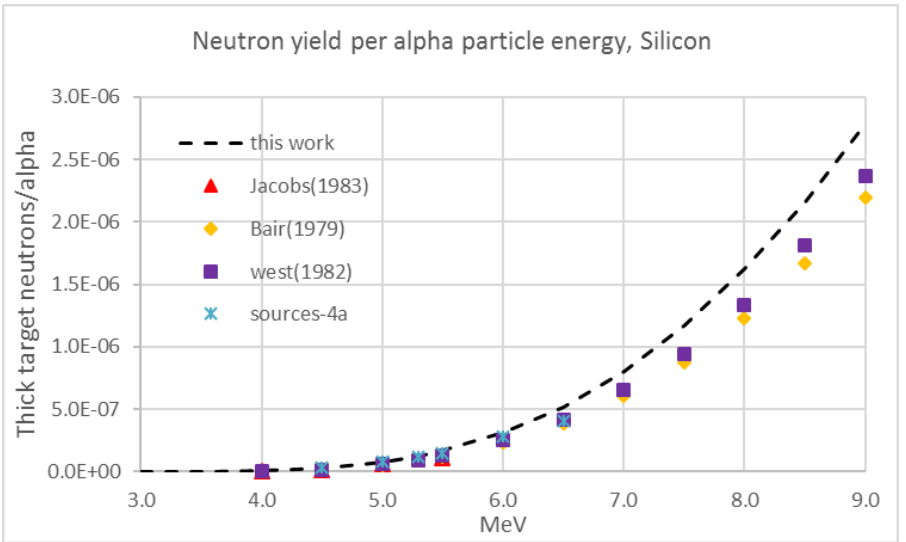
- The complemented (α,n) XS for Oxygen provides better agreement to measured data!

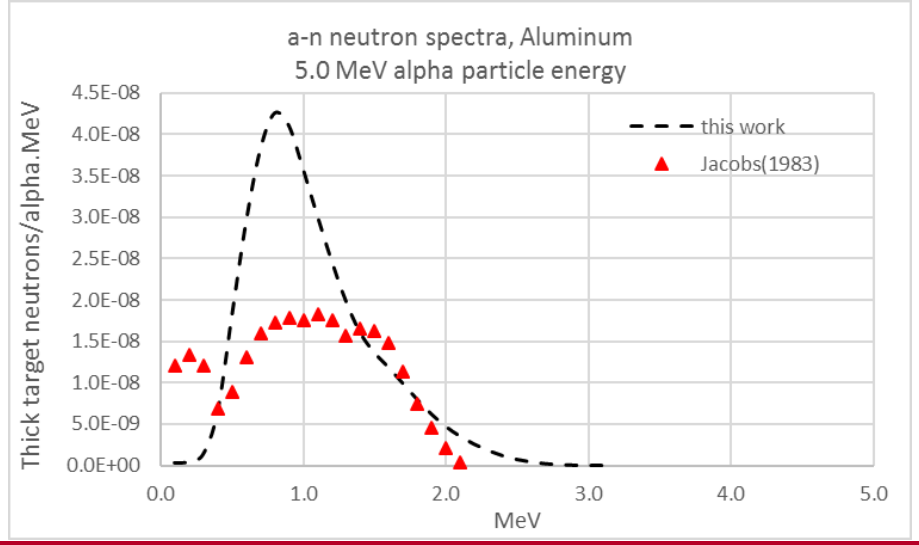


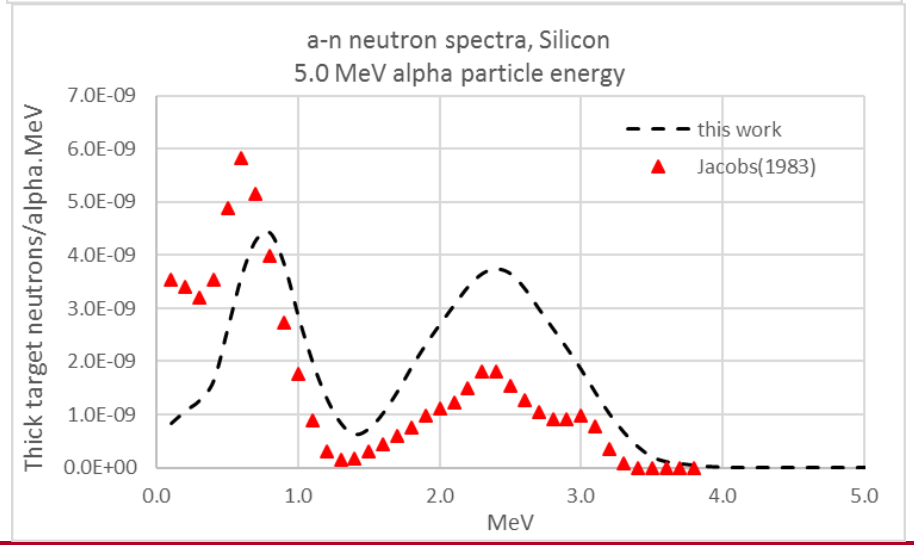
(α,n) neutron yields and spectra cont.

- Aluminum and Silicon: fairly good agreement for yields and a question mark for the spectra



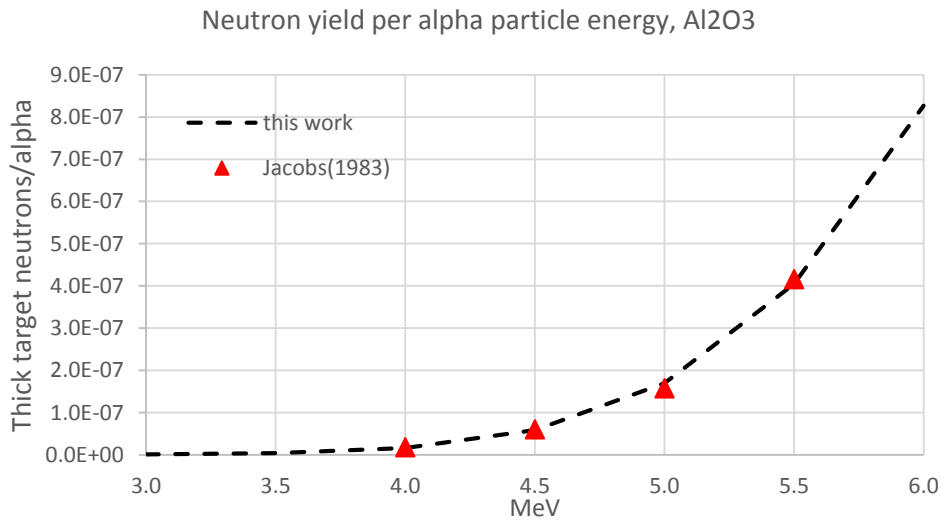


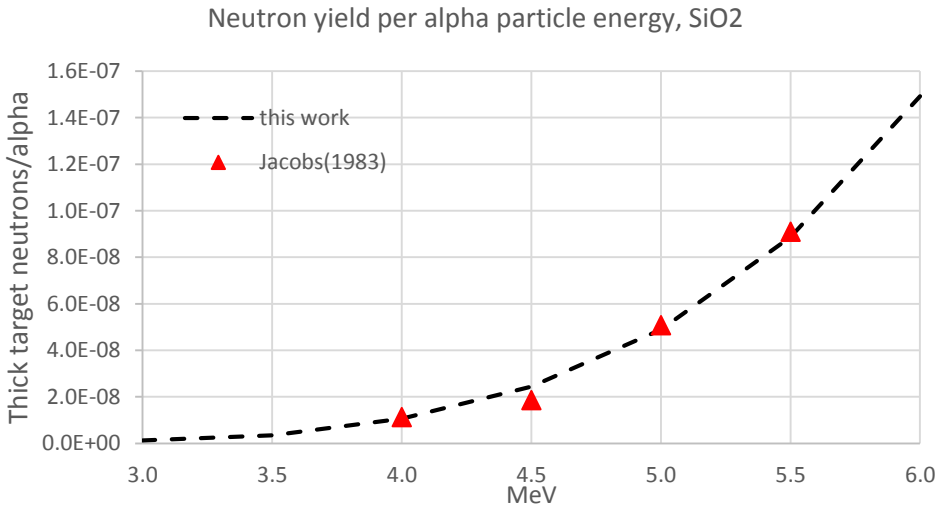


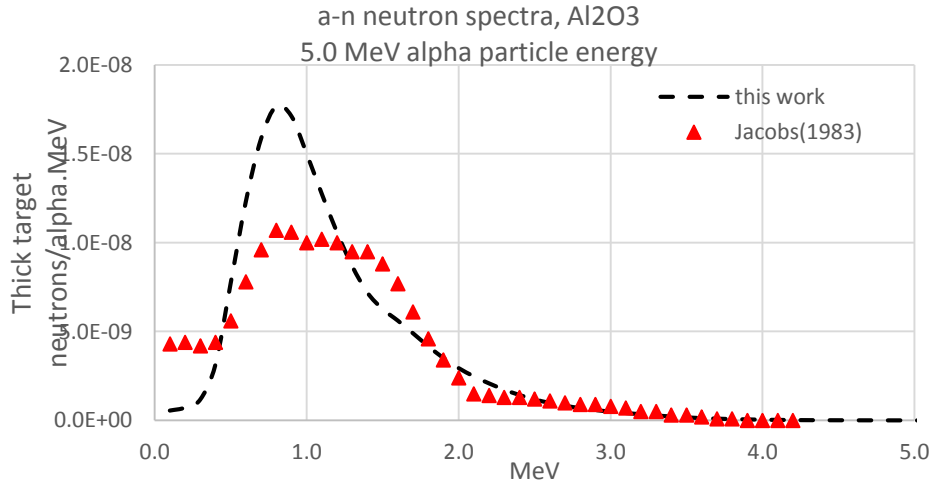


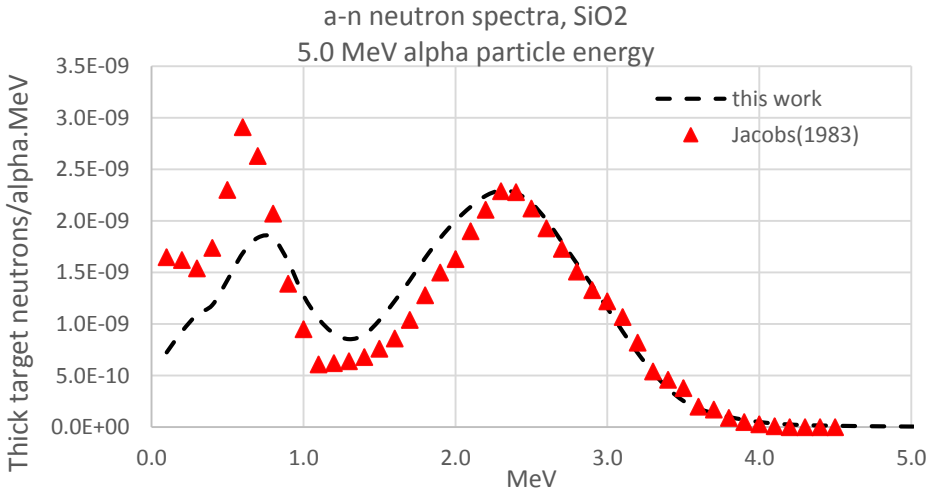
(α,n) neutron yields and spectra cont.

- Oxides of Aluminum and Silicon : good agreement for yields and a question mark for the spectra









Bremsstrahlung

- Challenges
  - NJOY-2012 does not (yet) process electron data
  - Vast majority of research/measurements are outside range of interest (<15 MeV)
    - Medical
    - Accelerators
    - Astrophysics
  - Need wide range of materials for waste applications
    - UO2
    - Metal alloys
    - Mixed silicides/oxides (vitrification)
  - Open question – how to generate bremsstrahlung emission spectrum for a mixture/compound?
    - Stoichiometric weighting
    - Charge weighting
    - Mass weighting (Dillman)

Bremsstrahlung – Compare to ESTAR

- Test case – UO2 Energy Yield
  - Present in ESTAR database
  - Happens to be rather important for spent fuel

Beta Energy	O (C/E)	U (C/E)	UO2 S (C/E)	UO2 M (C/E)
0.2 MeV	1.730	1.705	1.769	1.113
0.5	1.560	1.195	2.016	0.921
1.0	1.808	1.430	2.081	1.117
1.5	1.611	1.791	2.022	1.174
2.0	1.414	1.711	1.848	1.090
2.5	1.351	1.532	1.690	1.029
3.0	1.357	1.447	1.574	1.021
3.5	1.394	1.419	1.480	1.042
4.0	1.447	1.426	1.403	1.080
5.0	1.576	1.502	1.282	1.183

Summary and Open Issues

- A procedure for generating decay data is established and a set of decay data for all available isotopes (~3700) has been generated.
- The complete set of decay data for all available isotopes allows Studsvik to offer significantly extended isotopic nomenclature which would cover broad spectrum of spent fuel analyses with application to: reactor core safety, dry cask loading scenarios, criticality safety evaluation, accident source terms, shielding analyses and dose evaluation, vitrified fuel, etc.
- Bremsstrahlung is primary open issue
  - Data generation
  - Testing and verification
    - Measurements
    - Other codes

Studsvik

Bremsstrahlung

Bremsstrahlung photon yield

$$Y_{ph}\left(E,E_c\right)=\int_{E_c}^{E_j}\frac{\lambda^{-1}\left(E',E_c\right)}{-\frac{dE'}{dx}}dE'$$

Bremsstrahlung photon source

$$S_{brem}^{i}=\sum_{E_c}^{E_j}S_j^{\beta}Y_{ph}^{j}M_{ij}$$