Delayed Neutron Energy Spectrum from a Specific Precursor

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Participants
- Ivan Borzov
- Daniel Cano
- Satoshi Chiba
- Iris Dillmann
- Muriel Fallot
- Paul Garrett
- Robert Grzywac
- Xiaolong Huang
- Tomislav Marketin
- Futoshi Minato
- Gopal Mukherjee
- Vladimir Piksaikin
- Krzysztof Rykaczewski
- Balraj Singh
- José L. Tain

Advisers
- Daniel Abriola
- Tim Johnson
- Libby McCutchan
- Robert Mills
- Alejandro Sonzogni
- Valentina Semkova
- Naohiko Otsuka
- Marco Verpelli
- Stanislav Simakov

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IAEA CRP on a Reference Database for Beta-Delayed Neutron Emission Data

Project Officer: Paraskevi Demetriou

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3rd North-American Workshop on Beta-Delayed Neutron Emission

The workshop follows the previous meetings at McMaster University (2012) and at Oakridge National Laboratory (2013), and will take place from 25-27 July 2014 at Triumf, Canada, after the Nuclear Structure Conference. It is intended to present and coordinate experimental, theoretical and evaluation efforts on beta-delayed neutron emission, with focus on the US and Canada.

More information is available at the workshop website.

Systematics of beta-delayed neutron emission probabilities

A phenomenological model of the beta-delayed neutron-emission probability, based on a level density function, was developed. The effective level density systematics, empirically determined from the experimental data, have been modeled and used to determine beta-delayed neutron-emission probabilities. The work was performed by K. Miernik and is now published in PRC 88, 041301(R) (2013) [PDF]. Files containing the calculated data and graphical presentations can be downloaded from this [link].

1st RCM from 26-30 August 2013, at IAEA Headquarters, Vienna

The 1st Research Coordination Meeting of the CRP was held in Vienna, from 26-30 August 2013. Participants presented and discussed their ongoing activities and agreed upon the plan of work for the CRP. More information about the meeting can be found here.

IAEA Meetings
- 1st RCM 2013
- Consultants Meeting 2011

INDC (NDS) Documents
- INDC(NDS)-0599
- INDC(NDS)-0107/G

Workshops
- 1st North-American Workshop (McMasters Univ) 2012
- 2nd North-American Workshop 2013
- Workshop on Reactor Neutrinos 2013

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Delayed Neutron Emission from ^{137}I

S. Shalev and G. Rudstam, PRL,28,687,1978

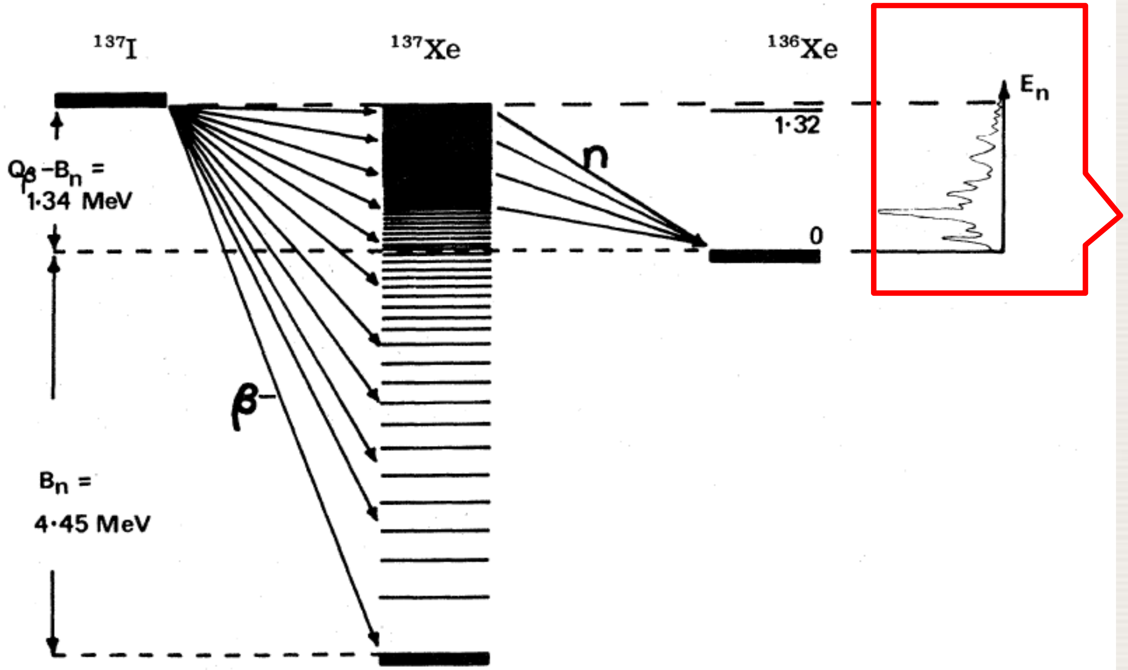

FIG. 2. Energy-level diagram for β-delayed neutron emission from ^{137}Xe.

Fine structure that reflects both decay characteristics of the precursor and the level structure of the daughter.

Nuclear reactor technology application

- The beta-delayed neutrons are essential from the point of view of reactor kinetics and safety. Large uncertainties in the delayed neutron data used in reactor calculations (for determining βeff) lead to costly conservatism in the design and operation of reactor control systems.
- Delayed neutron data are also necessary in summation calculations for determining the decay heat produced by the γ-rays and β-particles emitted by the β--decaying fission products.
- NEA WPEC Subgroup 6: "*The use of the recommended delayed neutron yields or ^{235}U, ^{238}U and ^{239}Pu lead to overall accuracies in the calculation of βeff of 3% for thermal systems and 2% for fast systems….. Additional work on delayed neutron data is necessary for satisfying new requirements emerging from the trends in reactor technologies. This affects in particular the nuclear data necessary for isotopes of interest for transmutation applications (^{237}Np, Am, Cm) and for the Thorium fuel cycle (^{232}Th and ^{233}U).*"

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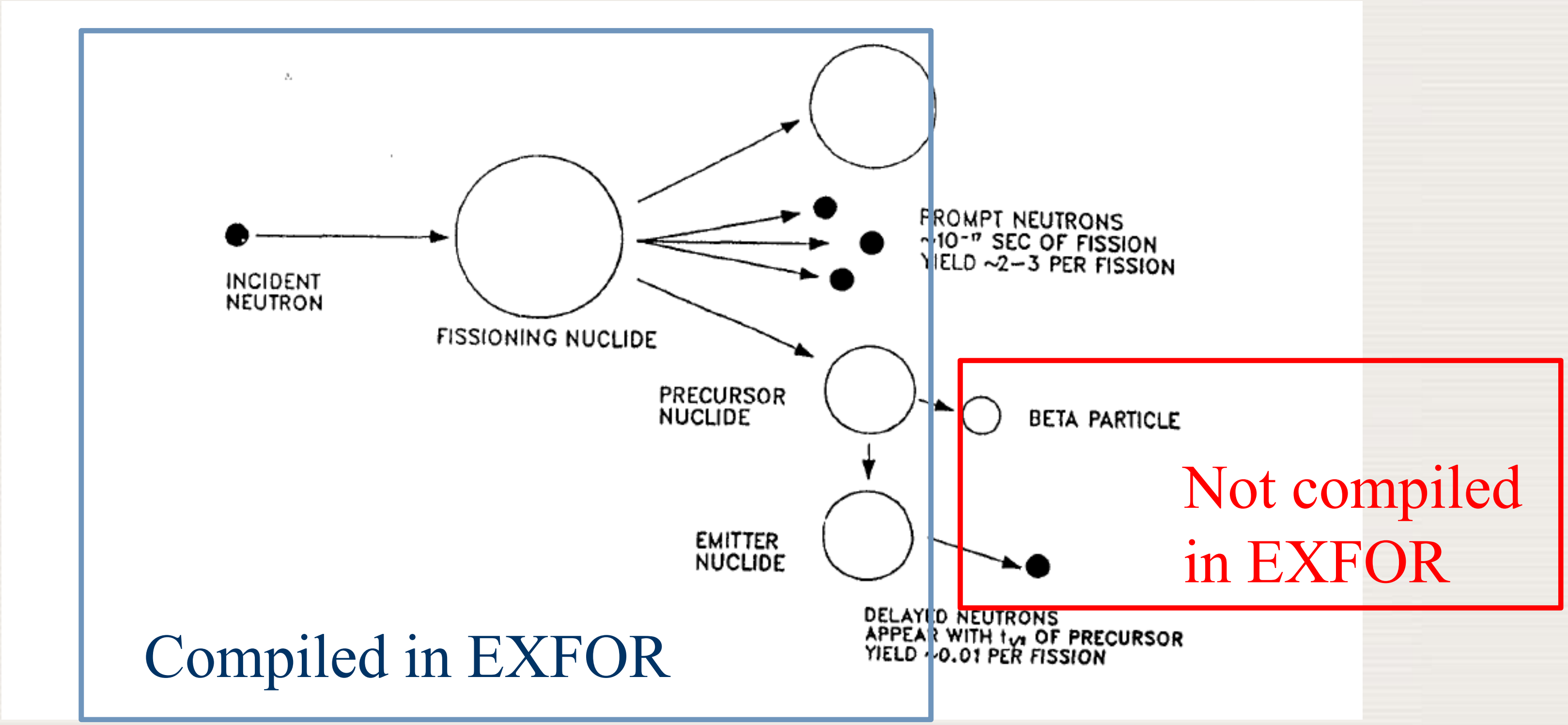

INCIDENT NEUTRON
FISSIONING NUCLIDE
PROMPT NEUTRONS
~10⁻¹⁷ SEC OF FISSION
YIELD ~2–3 PER FISSION
PRECURSOR NUCLIDE
BETA PARTICLE
EMITTER NUCLIDE
DELAYED NEUTRONS
APPEAR WITH t1/2 OF PRECURSOR
YIELD ~0.01 PER FISSION
Compiled in EXFOR
Not compiled in EXFOR

Needs II: Nuclear (astro)physics

Measuring the neutrons from βn emitters offers a very simple way to determine several nuclear physics parameters at once.

- From the time dependence of the neutron emission one can deduce the half-life of the precursor.
- Also other important nuclear structure information can be deduced: from the neutron emission probability (Pn value) the β-strength above the neutron separation energy (Sn) can be deduced, whereas the low-lying strength defines the half-life of the daughter isotope.

Important information for shell model calculations.

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Methods for β-delayed neutron measurements I

- In recent years novel detectors have been built to operate at major accelerator facilities to measure the delayed-neutron decay characteristics of individual precursors, in synergy with quantification of aggregate properties involved in the fissile materials.
- Beta-delayed neutron precursors are produced by neutron induced fission, proton induced fission, heavy-ion induced fragmentation, light-ion induced spallation LCP<=4 and extracted by mass spectrometry.

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Methods for β-delayed neutron measurements II

- n-β Neutrons and β counted separately
- β/n coincidence method
- γ AZ+n”: Abundance of precursor determined via γ-counting of any β-decay daughter
- Pn Normalization with respect to a known Pn value
- “fiss”: Determination of the number of precursors by fission yields
- “γ-γ”: pure γ-counting technique to determine both the number of mothers and βnnuclei (granddaughters) produced
- Ion-recoil method: This method includes the trap measurements It uses the recoil ions and time-of-flight measurement to deduce the neutron spectrum and can be complemented with γ-detectors.

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LEXFOR update I

Decay Properties of Fission Product Nucleus *(new entry)*

There are delayed-neutron quantities that are not properties of the fissioning nucleus but of the fission-product nucleus that is the "precursor" of the delayed neutron, e.g., **delayed-neutron emission probability**, **delayed-neutron energy spectrum** for a specific precursor. They may be also compiled in EXFOR for users although they are not reaction data. Delayed neutron quantities for a specific precursor can be studied not only by production of the precursor by fission but can be also by other method (*e.g.*, light-induced spallation, heavy-ion induced fragmentation) [7].

Delayed-Neutron Emission Probability (Pn value)

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LEXFOR update II

Delayed-Neutron Energy Spectrum for a Specific Precursor (*New entry*)

REACTION Coding: (Z-S-A(0,B-)Z'-S'-A',,PN/DE)

where: *Z-S-A* is the precursor nucleus before decay);

Units: a code from Dictionary 25 with dimension PNDE (*e.g.*, PC/DEC/MEV)

Examples:

(Z-S-A(0,B-)Z'-S'-A,,PN/DE) β-delayed neutron spectrum in neutrons/100 decays/MeV or neutrons/decay/MeV

(Z-S-A(0,B-)Z'-S'-A',,PN/DE,,NPD) β-delayed neutron spectrum normalized to the probability distribution

(Z-S-A(0,B-)Z'-S'-A',,PN/DE,,REL) β-delayed neutron spectrum in arbitrary unit

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LEXFOR update III

Data not Presently Compiled in EXFOR

 The energy spectrum of all delayed neutrons together, which is time dependent, due to the contributions from the different half-life groups.

 The delayed-neutron equilibrium spectrum as found in a steady-state reactor.

 ~~Delayed-neutron energy spectrum from individual precursor~~

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