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CEA-LANL efforts on nuclear reaction theories and their application to nuclear data

T. Kawano
Theoretical Division

Cooperative Projects between CEA/DAM and LANL/T

under CEA/NNSA Research Agreement

- **P140: Collaborative Exchanges of Nuclear Reaction Algorithms and Data**
  - development of a broad range of nuclear reaction and structure theories
  - in-person meeting series started in 2005
- **P141: Uncertainties and Covariances in Nuclear Data and Application to Plutonium**
  - uncertainty quantification methodology
  - comparison of evaluated covariances
  - recently the scope was expanded to include ML for many other target nuclei
- **P161: Evaluations of Neutron Cross Sections on Prompt Fission Products**
  - produce fission product average cross section by model calculations
  - final result published in 2010, and merged to P140 in 2011
- **P186: Advanced Fission Cross Section Modeling**
  - now part of P140

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Importance of In-Person Meetings for New Ideas

- **Mutual visits started in Dec. 2003**
  - Informal meetings at CEA hosted by E. Bauge, every 2-3 years
    - US participants: M.B. Chadwick, T. Kawano, P. Talou, A. Kerman, F. Dietrich
  - Recently the meeting became slightly formal, biennial, hosted by S. Hilaire and M. Dupuis
    - participants expanded: I. Stetcu, A.E. Lovell, M.R. Mumpower, H. Sasaki (LANL), R. Capote (IAEA), M. Kerveno, G. Henning (IPHC/CNRS Strasbourg), P. Tamagno (CEA/DEN), …
  - 4 virtual meetings during COVID (2022)
  - E. Bauge visited LANL in 2005
    - uncertainty quantifications by Monte Carlo technique
  - P. Chau visited LANL in 2016
    - Engelbrech-Weidenmueller transformation implemented in TALYS

Microscopic Theory for Nuclear Applications

- **Eric Bauge always had a broad spectrum of nuclear physicists, from fully microscopic modeling to nuclear data applications**

  - JLM optical potential primarily adopted at CEA

  - Microscopic nuclear structure theories (HF-B) for nuclear reaction calculations

  - Microscopic description of pre-equilibrium process

    - Still active topic, see Dupui's talk

    - New collaboration includes experimental group at Strasbourg

  - Uncertainty quantification by employing Monte Carlo technique

- **Stimulate nuclear data community by organizing/participating international conferences**

  - Organized P(ND)^2 in 2005 and 2014

  - Actively participate in Varenna conference, CNR, and Covariance

Microscopic View

Macroscopic View

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2008 CEA Visit

- **Exact formulation of Hauser-Feshbach for deformed nuclei**

  - Detailed balance in the coupled-channel transmission coefficient

    - Later final formulation published in PRC in 2016

- **Lo-Fi covariance project**

  - Simple estimate of nuclear data covariance by applying GNASH-KALMAN method

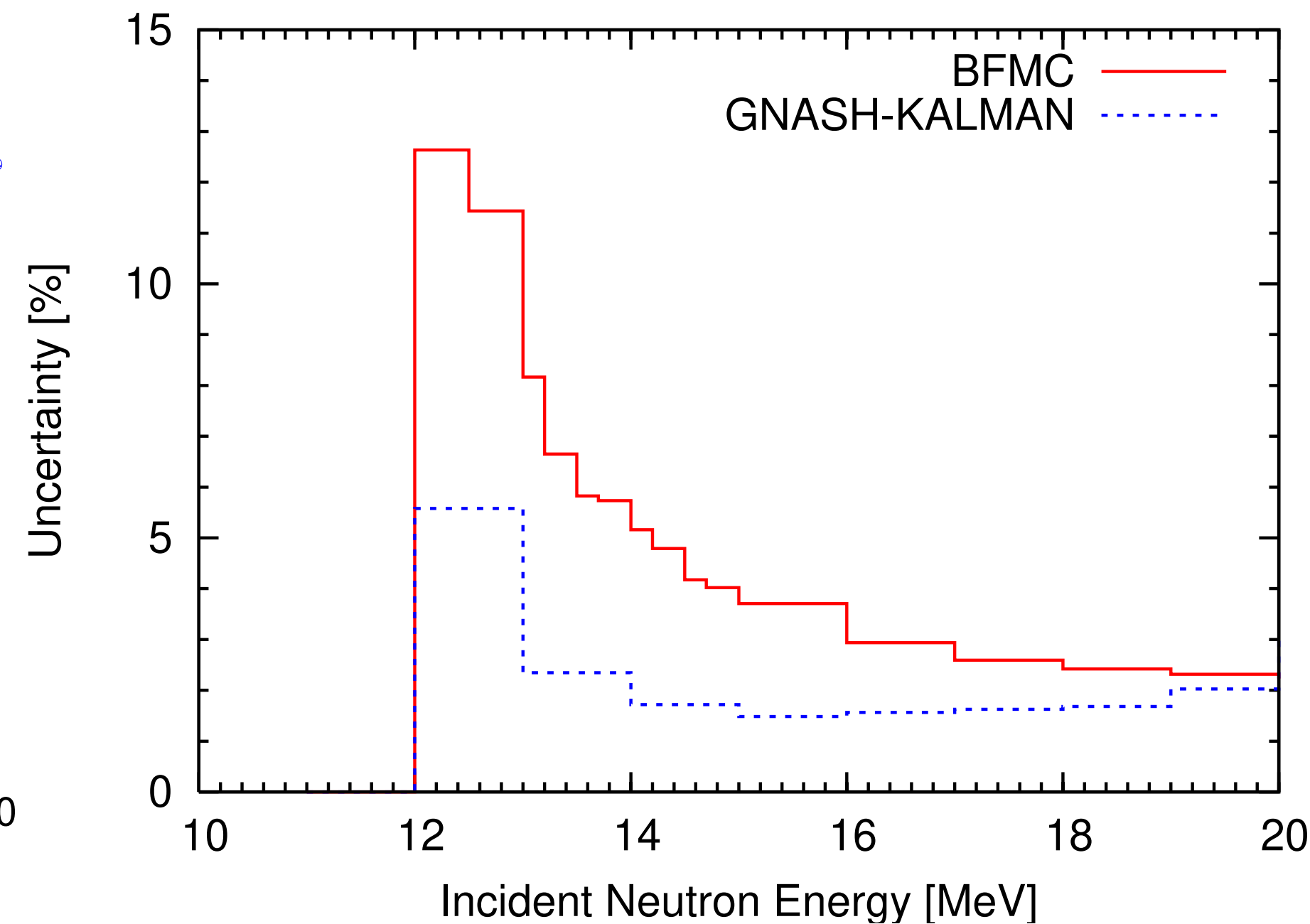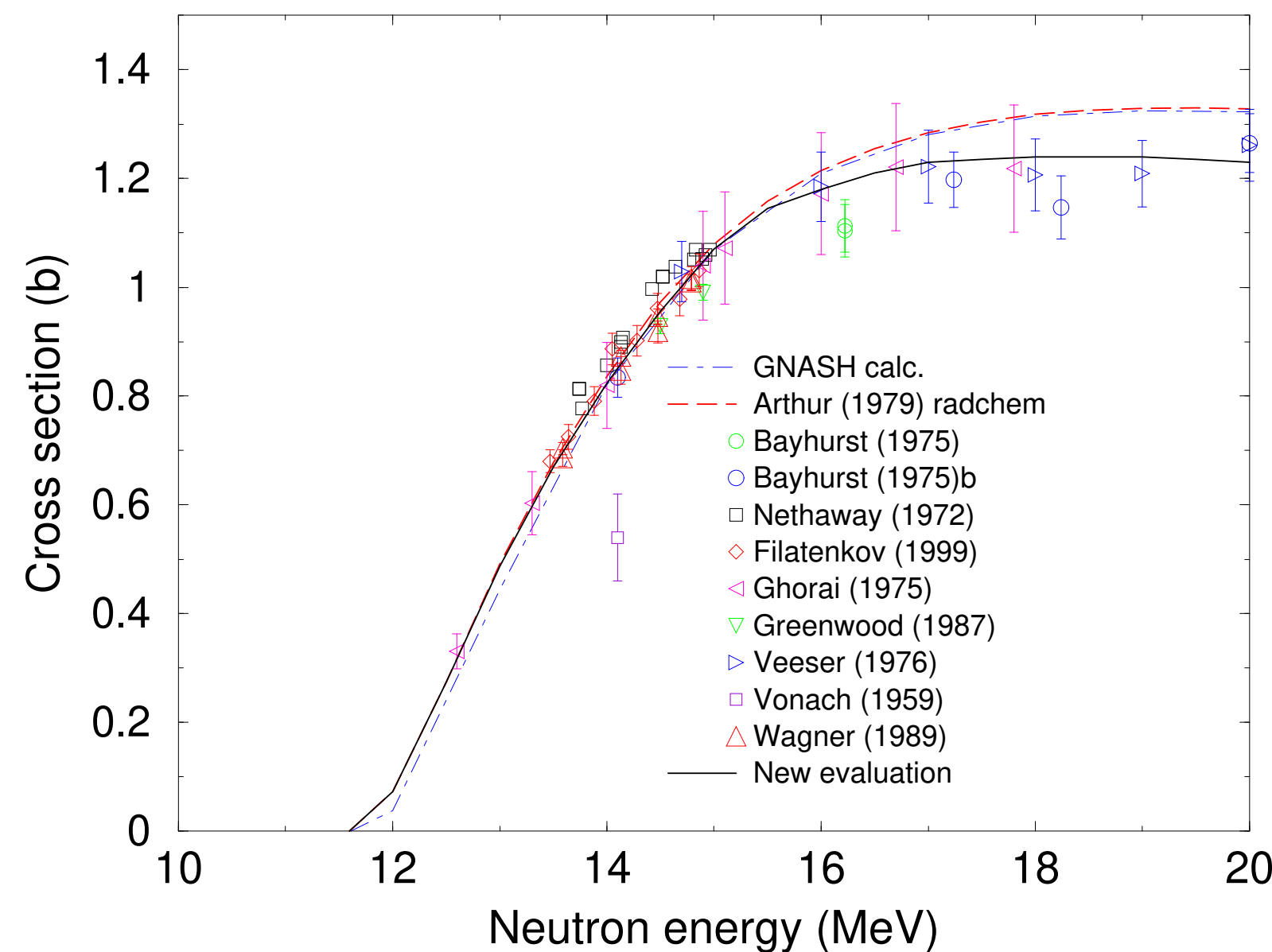- **Bauge was always watching new developments at Los Alamos**
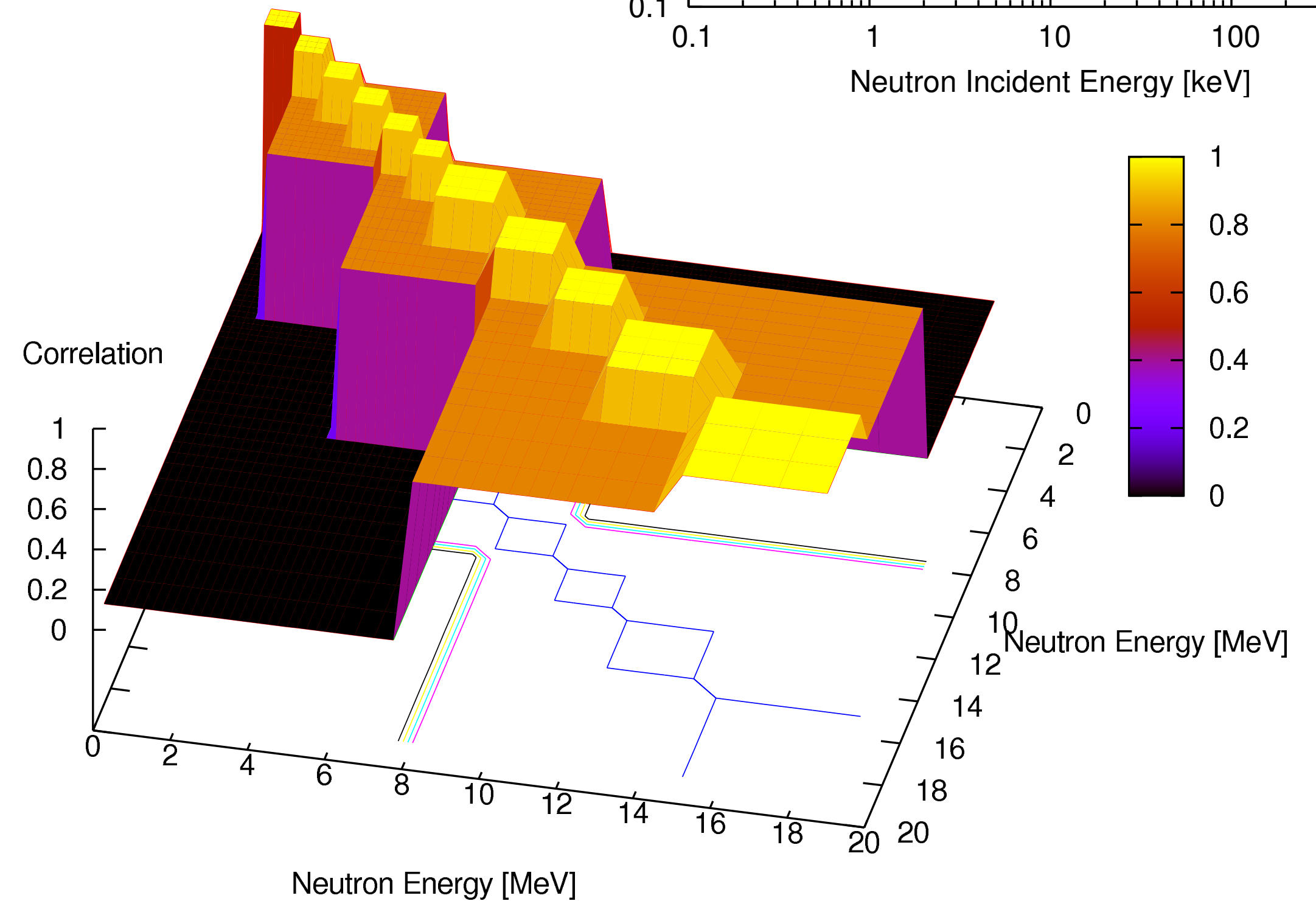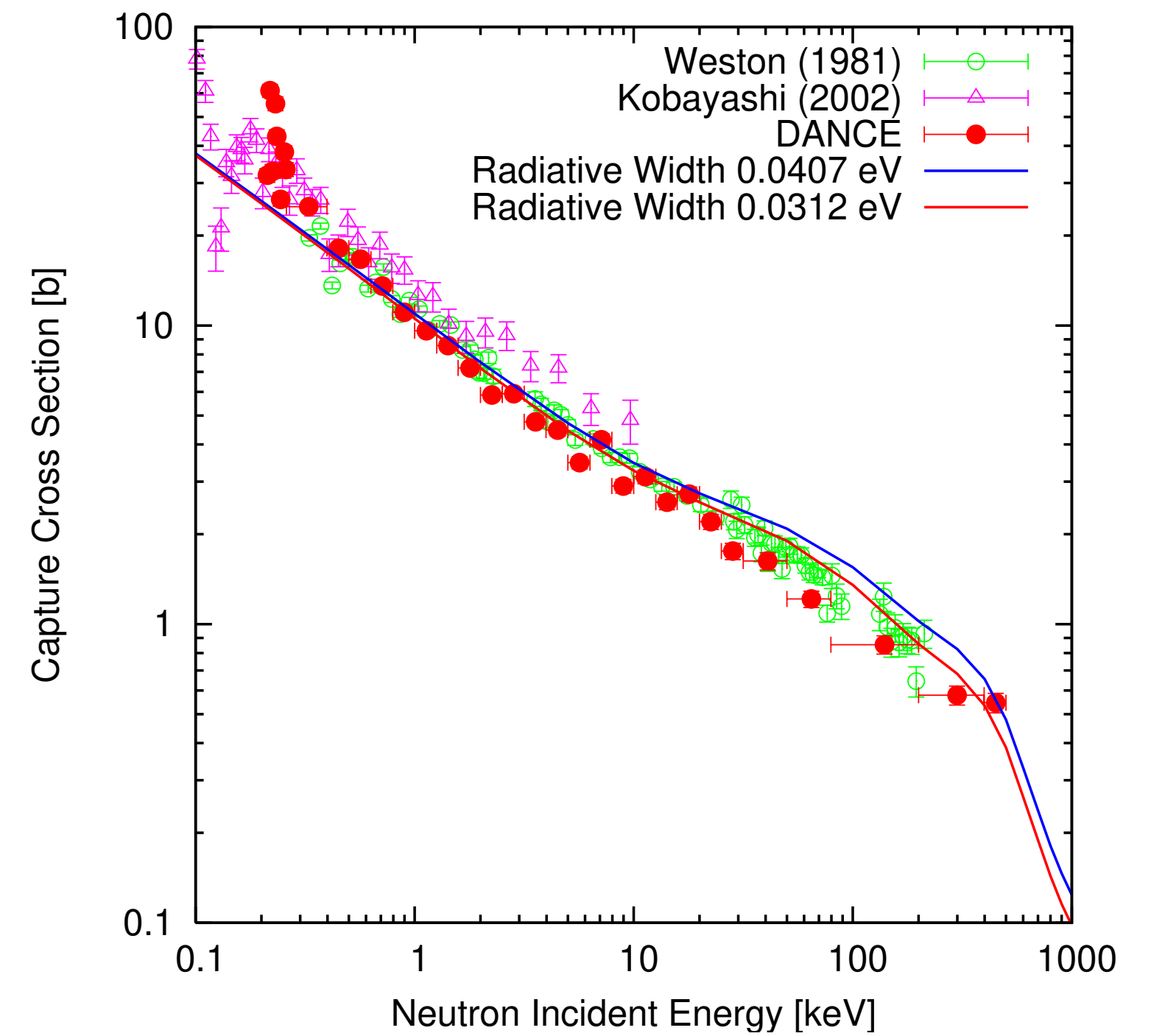
Comparison of Evaluated Covariances - Yttrium

- **Different approaches to evaluate covariance of 89Y(n,2n) cross section**

  - CEA: Backward-Forward Monte Carlo method with TALYS

  - LANL: GNASH-KALMAN method
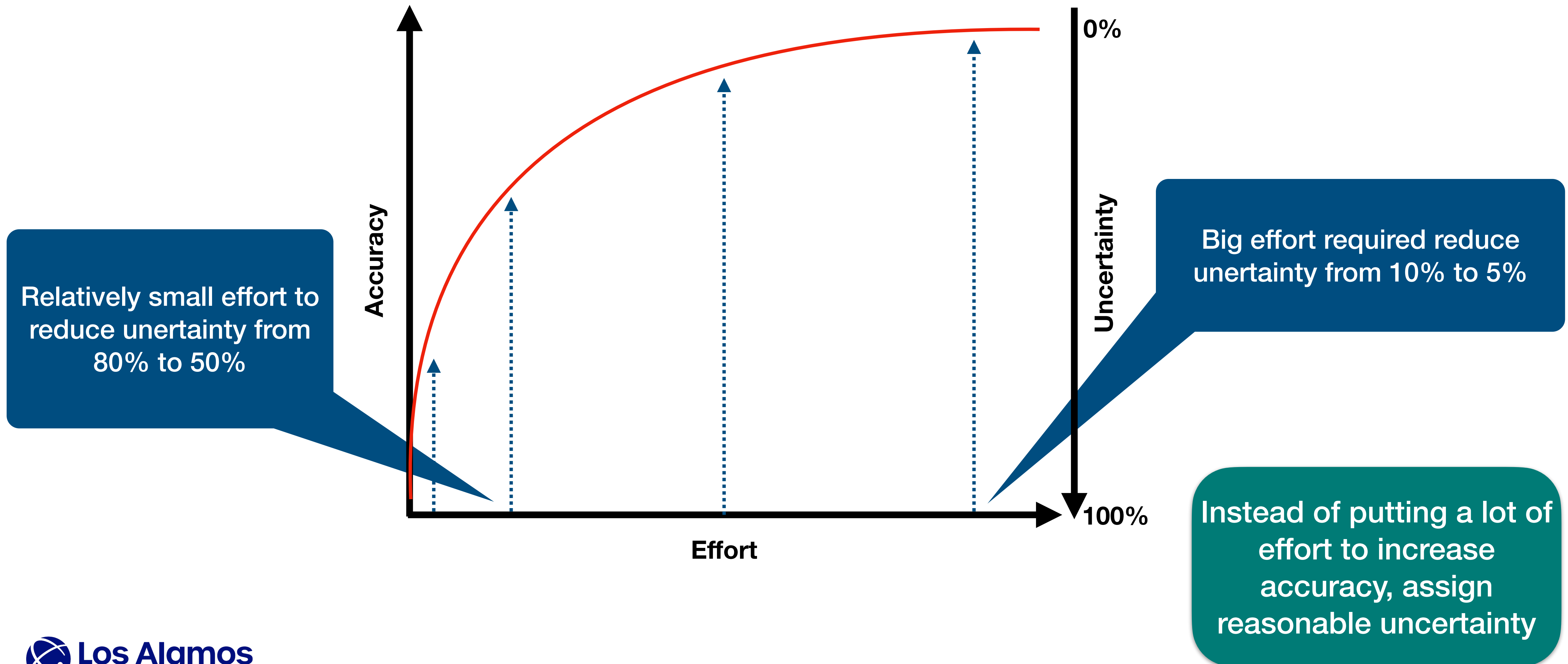
 - result published in NDS 108, 2742 (2008)
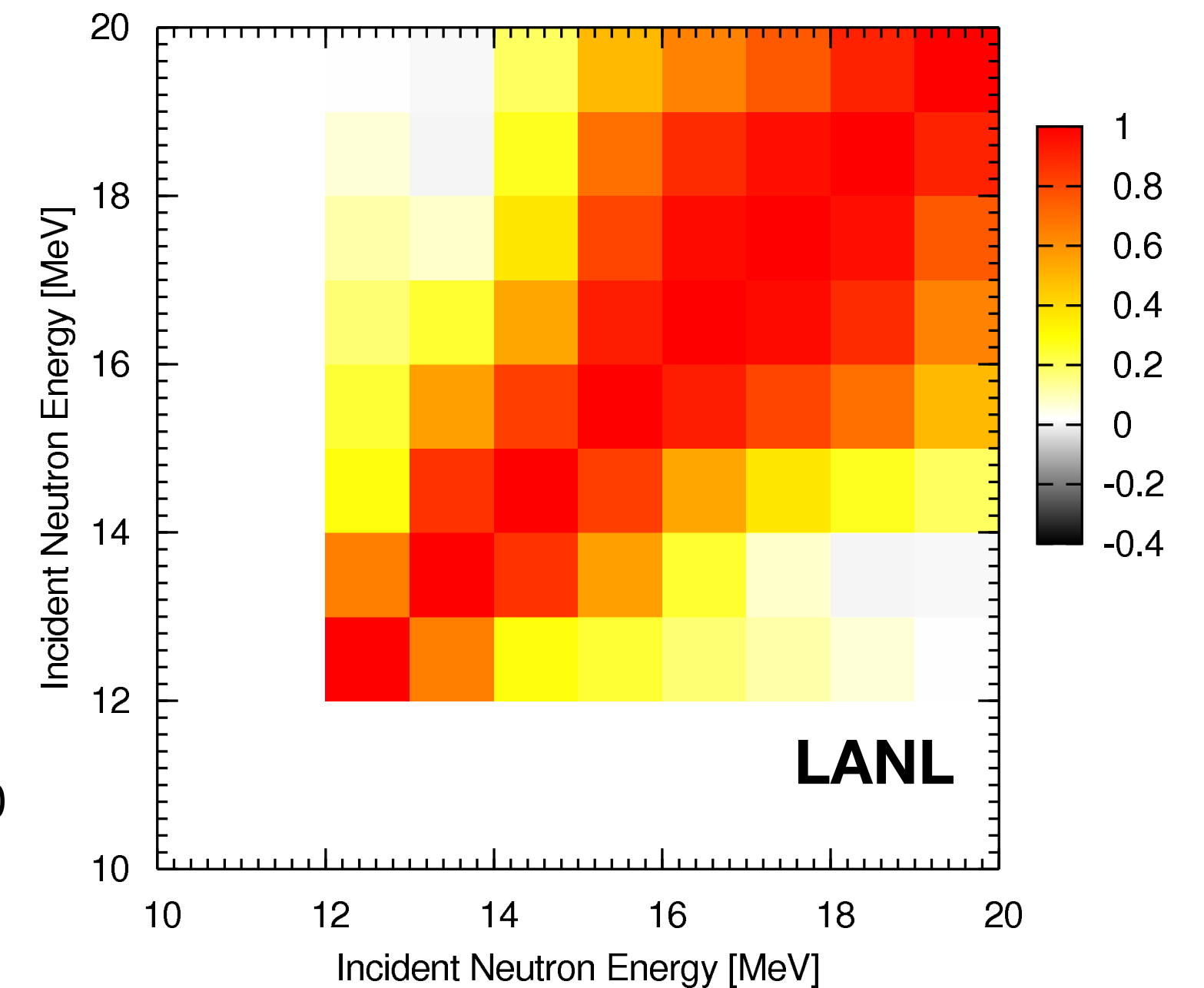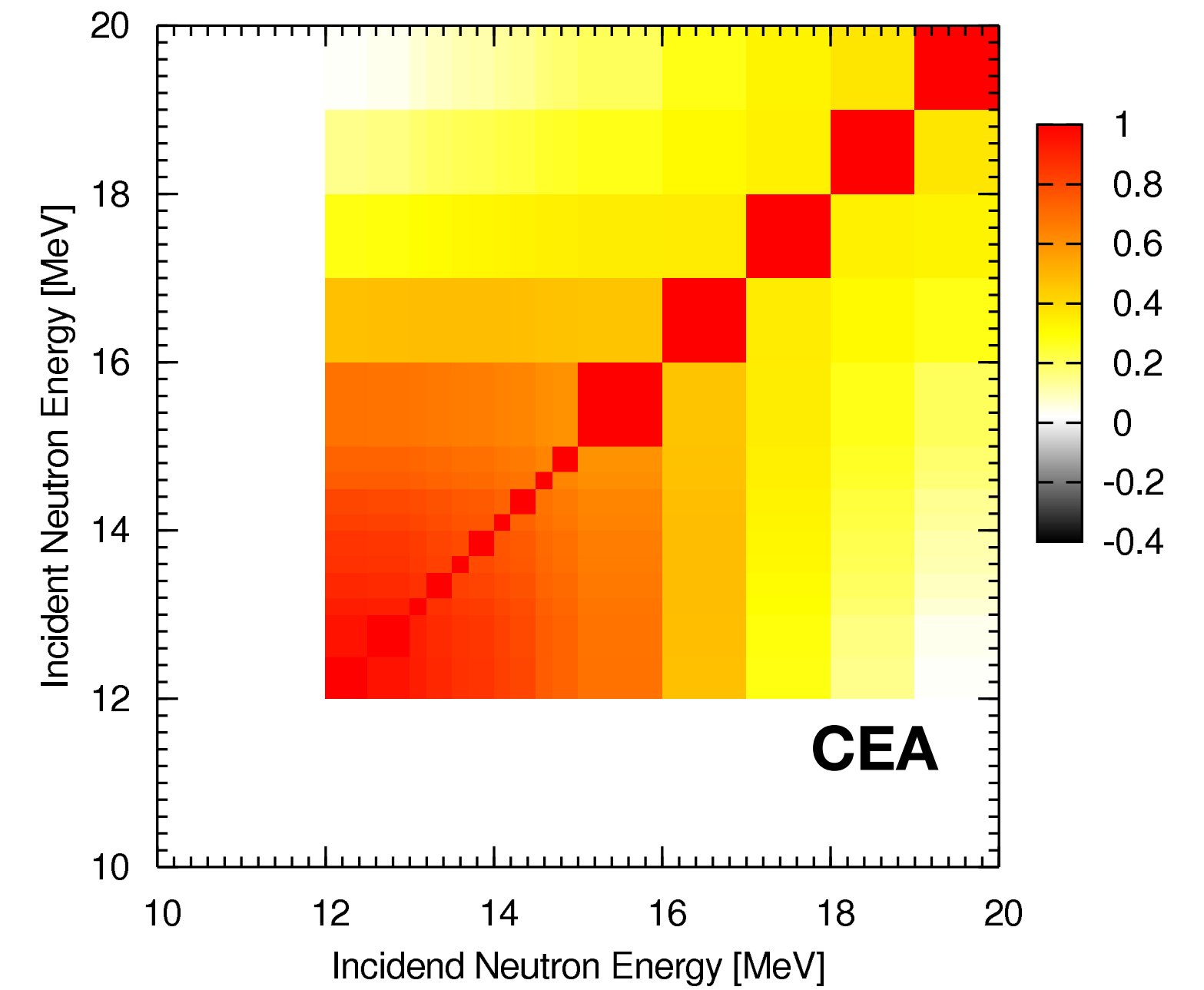
^{89}Y(n,2n) cross section

Eric Bauge's Effort - Accuracy Curve

- From Eric's presentation at LANL in 2008

Relatively small effort to reduce unertainty from 80% to 50%

Big effort required reduce unertainty from 10% to 5%

Instead of putting a lot of effort to increase accuracy, assign reasonable uncertainty

Accuracy

Uncertainty

0%

100%

Effort

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Prompt Fission Product Average Cross Section

- **(n,2n), (n,3n), and capture cross section averaged over FPY**
  - Pseudo-FP nuclear data represent all the FPs
- **FP cross sections calculated with GNASH, EMPIRE, TALYS**
  - Foster and Arthur employed 10 representative FPs (1982)
  - Nelson and Devlin included 34 FPs (2006)
  - Watanabe demonstrated this average never converges
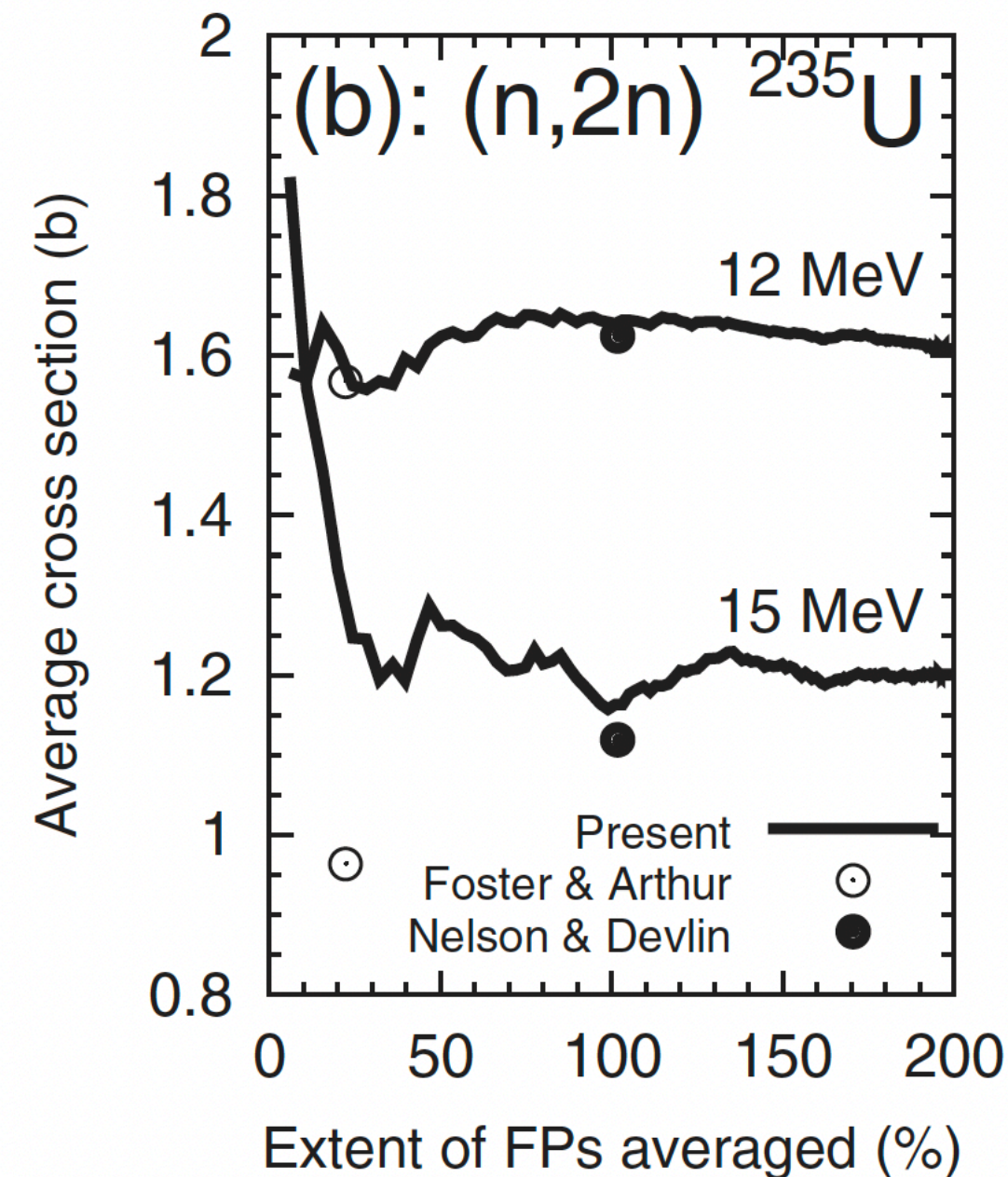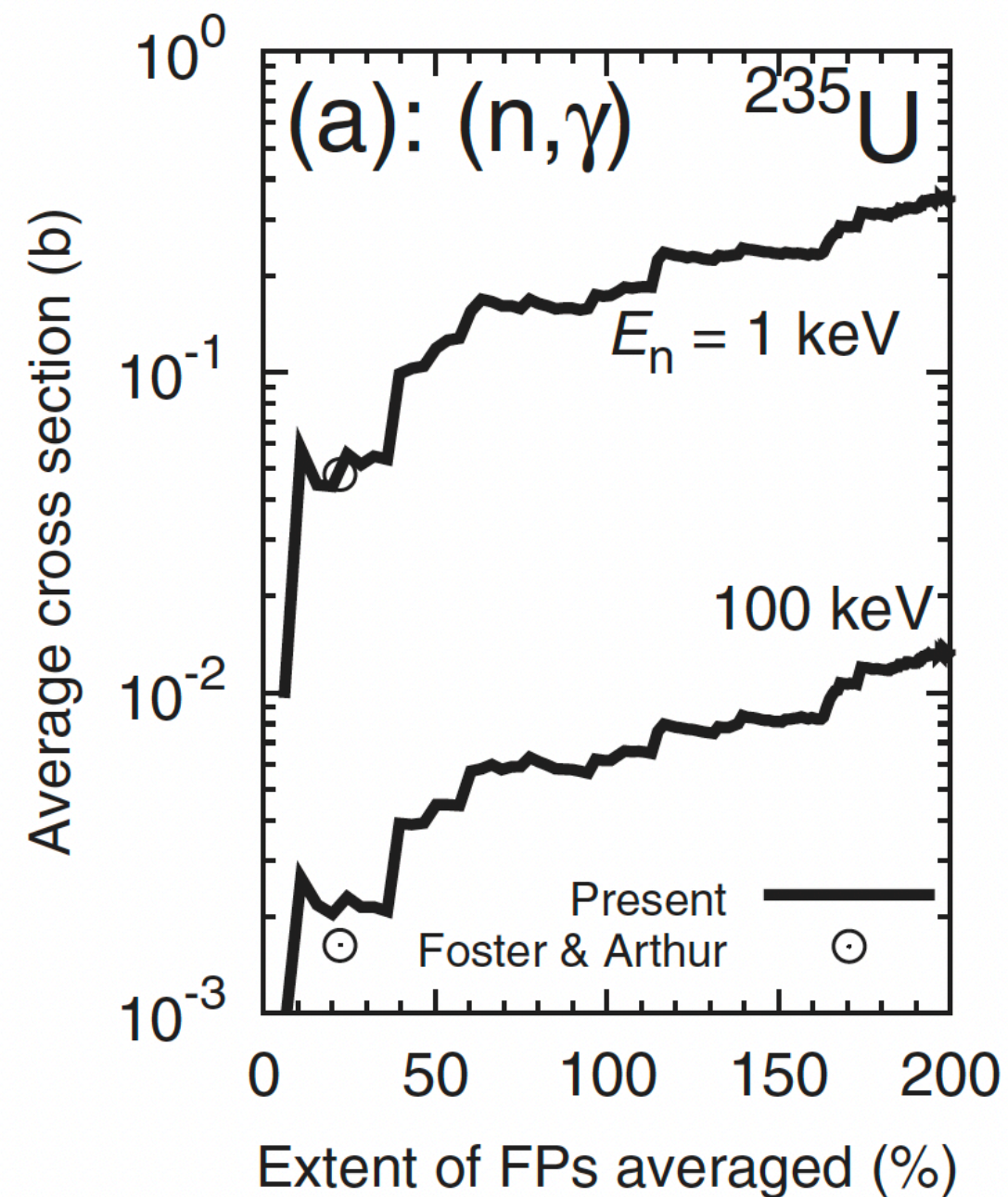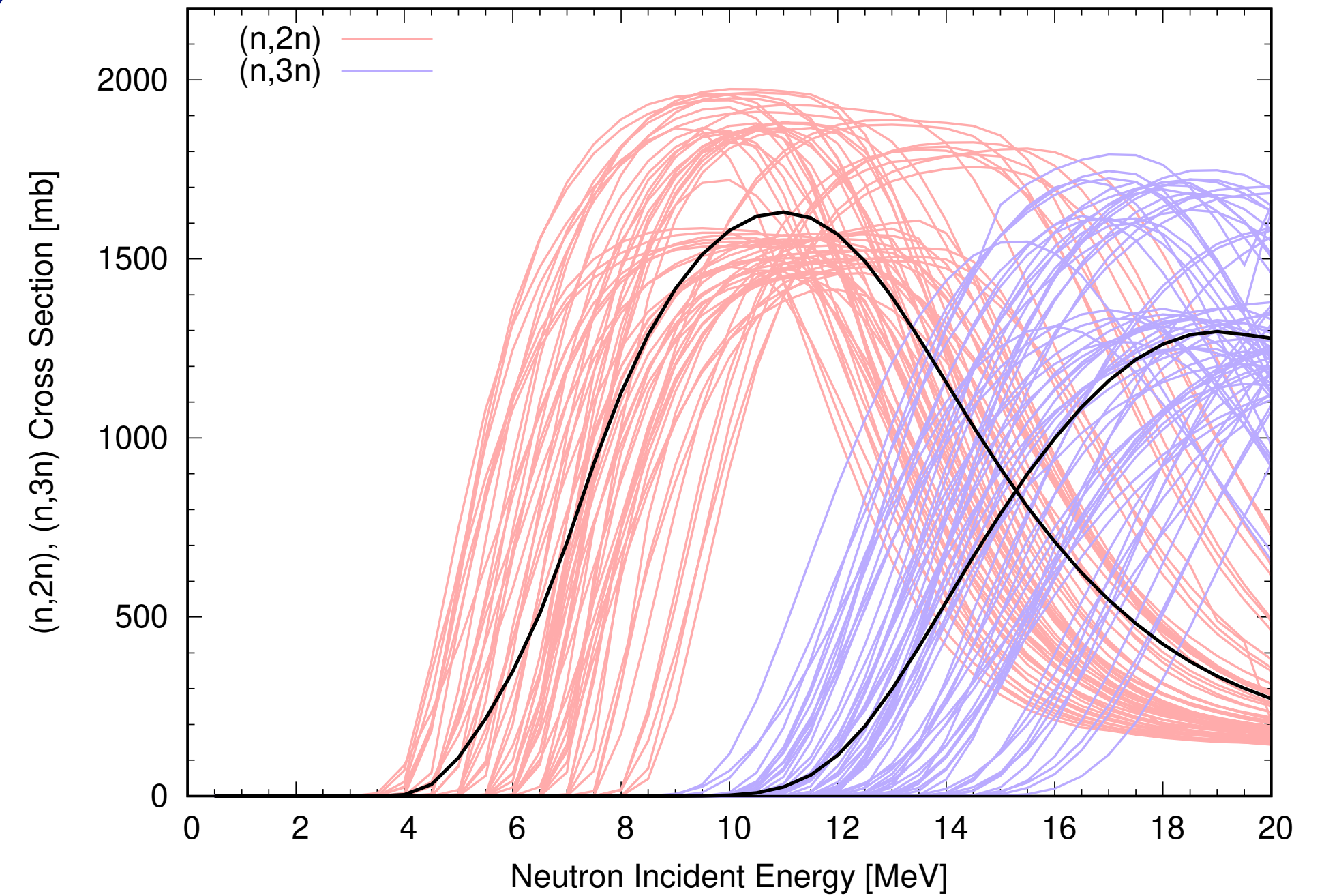
**Calculation of Prompt Fission Product Average Cross Sections
for Neutron-Induced Fission of ^{235}U and ^{239}Pu**

Takehito WATANABE[1,*], Toshihiko KAWANO[1], Mark B. CHADWICK[1], Ronald O. NELSON[2],
Stephane HILAIRE[3], Erick BAUGE[3] and Pierre DOSSANTOS-UZARRALDE[3]

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Significant Progress in Theoretical Nuclear Reaction Physics

- **Collaboration between CEA and LANL achieved several important milestones**

M1 impact on capture

Isomeric ratio measurements for the radiative neutron capture ^{176}Lu(n,γ) at the LANL DANCE facility

D. Denis-Petit,[1,*] O. Roig,[1] V. Méot,[1] B. Morillon,[1] P. Romain,[1] M. Jandel,[2] T. Kawano,[2] D. J. Vieira,[2] E. M. Bond,[2]
T. A. Bredeweg,[2] A.

Fission prediction

CC-HF formalism

Statistical Hauser-Feshbach theory with width-fluctuation correction including direct reaction channels for neutron-induced reactions at low energies

T. Kawano[*]
Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

R. Capote
NAPC–Nuclear Data Section, International Atomic Energy Agency, Vienna A-1400, Austria

S. Hilaire and P. Chau Huu-Tai
CEA, DAM, DIF, F-91297 Arpajon, France

Solving the one-dimensional penetration problem for the fission channel in the statistical Hauser-Feshbach theory
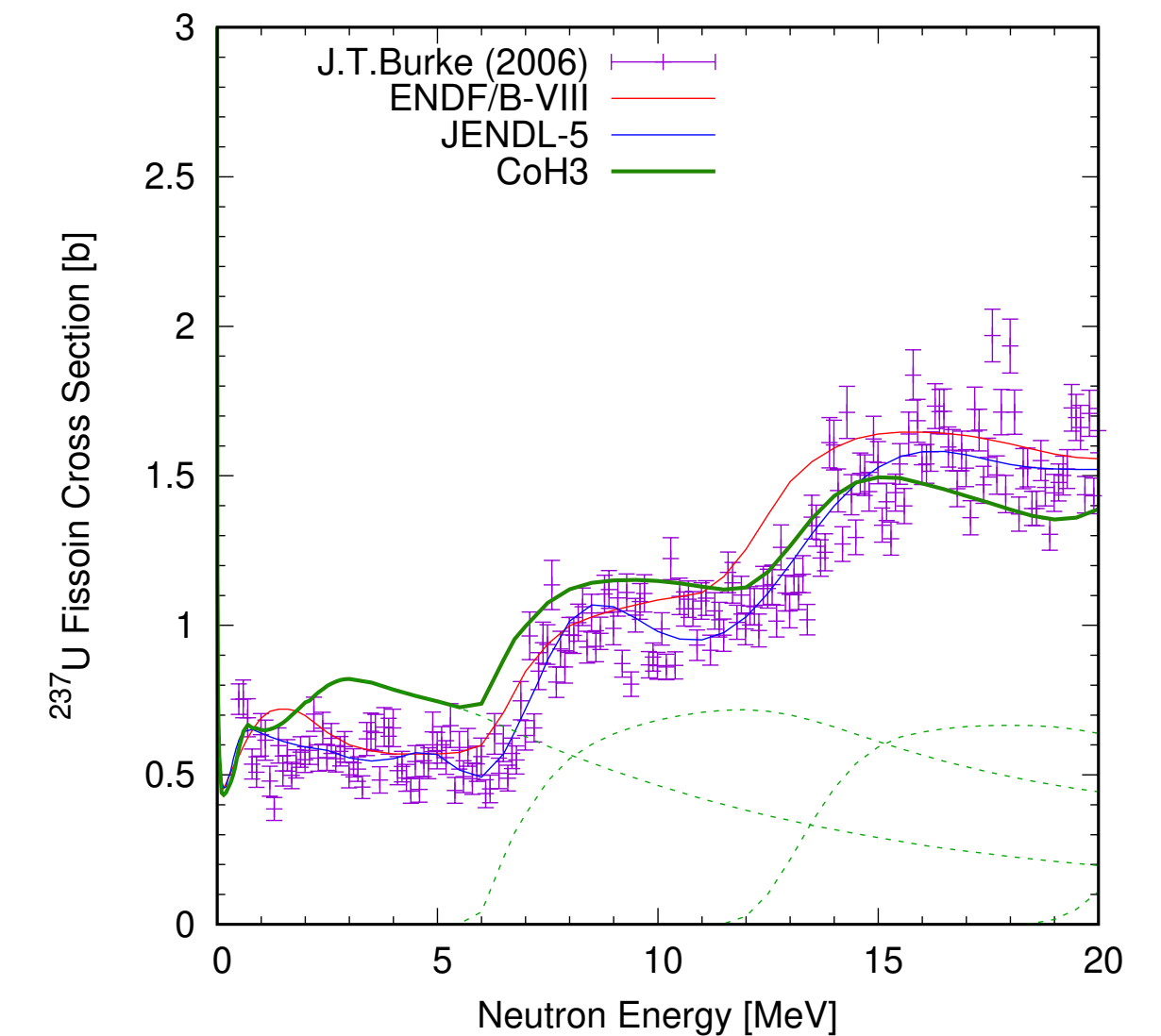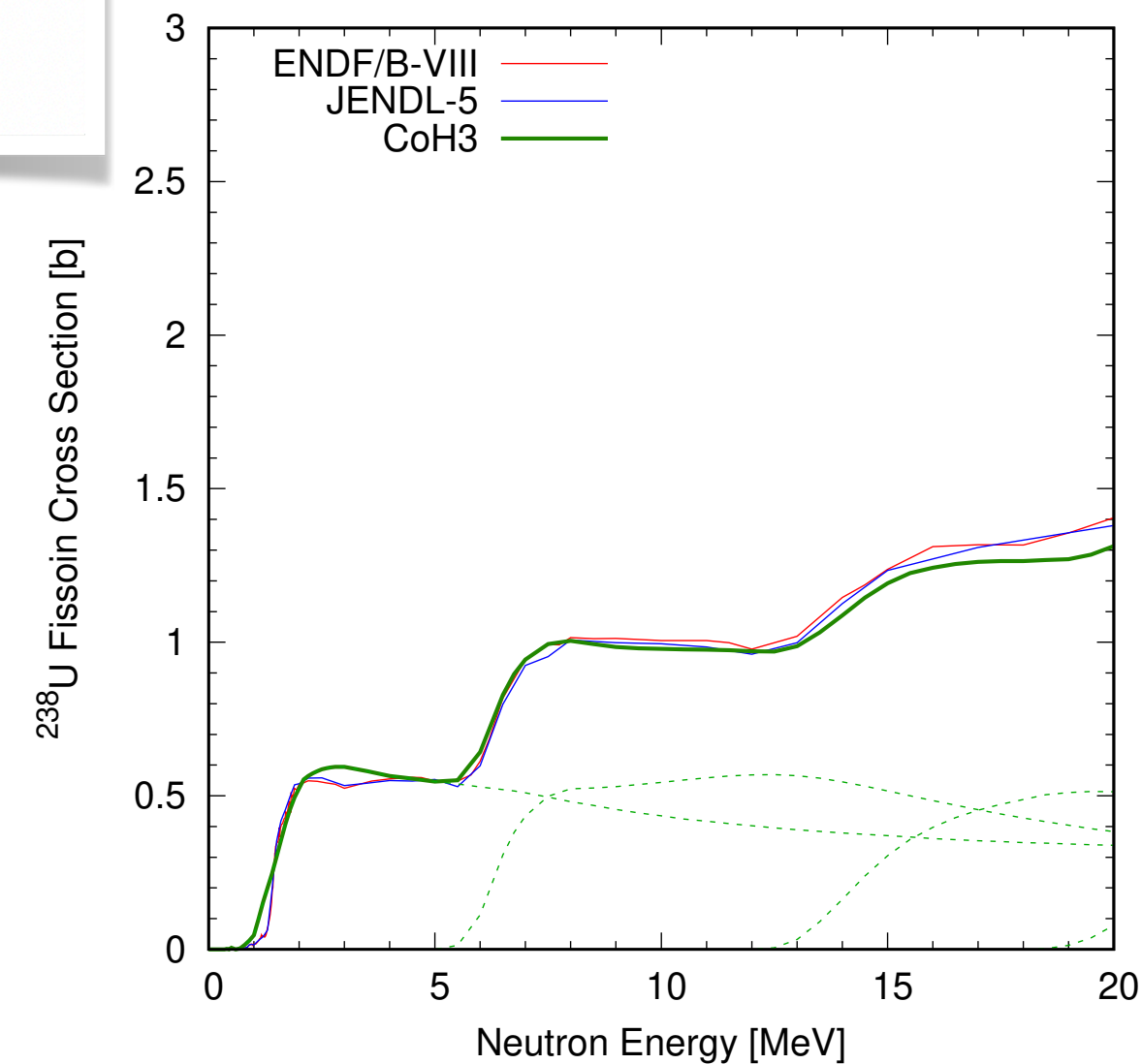
T. Kawano,[1,*] P. Talou,[1,†] and S. Hilaire[2,3]
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[3]*Université Paris-Saclay, CEA, LMCE, F-91680 Bruyères-le-Châtel, France*

Measurement of ^{238}U$(n, n'\gamma)$ cross section data and their impact on reaction models

M. Kerveno,[1,*] M. Dupuis,[2,3] A. Bacquias,[1] F. Belloni,[4] D. Bernard,[5] C. Borcea,[6] M. Boromiza,[6] R. Capote,[7]
C. De Saint Jean,[2,3] P. Dessagne,[1] J. C. Drohé,[4] G. Henning,[1] S. Hilaire,[2,3] T. Kawano,[8] P. Leconte,[5] N. Nankov,[4] A. Negret,[6]
M. Nyman,[4] A. Olacel,[6] A. J. M. Plompen,[4] P. Romain,[2,3] C. Rouki,[4] G. Rudolf,[1] M. Stanoiu,[6] and R. Wynants[4]
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QM effect on inelastic gamma

Concluding Remarks

- **CEA-NNSA cooperative research agreement**
  - Exchange ideas and new development on nuclear reaction and structure theories
  - Biennial in-person meetings, always meeting report produced
  - Produced several publications - PRC, NDS, JNST

- **Eric Bauge's enthusiasm for fundamental and applied nuclear physics fields**
  - Microscopically calculated nuclear properties, such as nuclear mass, level densities, GDR, nuclear mass, fission potential energy surface, etc., utilized in nuclear reaction calculations
    - All staff members at Bruyeres have significant contributions
  - Encouraged collaboration with LANL, where often phenomenological approaches are taken