IAEA 60 Years
Atoms for Peace and Development

TENDL-2021 library for (α ,n) cross sections

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IAEA Technical Meeting on (alpha,n) nuclear data evaluation and data needs, November 8-12 2021, IAEA (virtual)

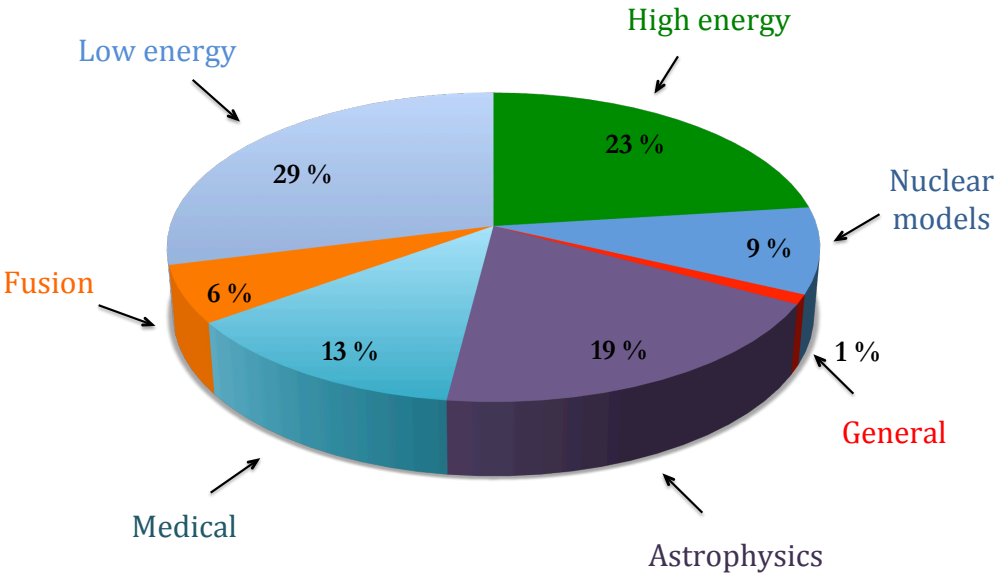
Contents

- Introduction
- TENDL: TALYS Evaluated Nuclear Data Library
- Nuclear reaction models relevant for (α ,n)
- Examples
- Summary

Introduction

- (α ,n) is an important reaction channel:
  - Non-proliferation/safeguards, criticality
  - Astrophysics: Dark matter, neutrons, nucleosynthesis
  - Medical isotope production
  - Detector simulation
  - Fusion
- Requires efforts in measurements, theory and nuclear data evaluation and validation

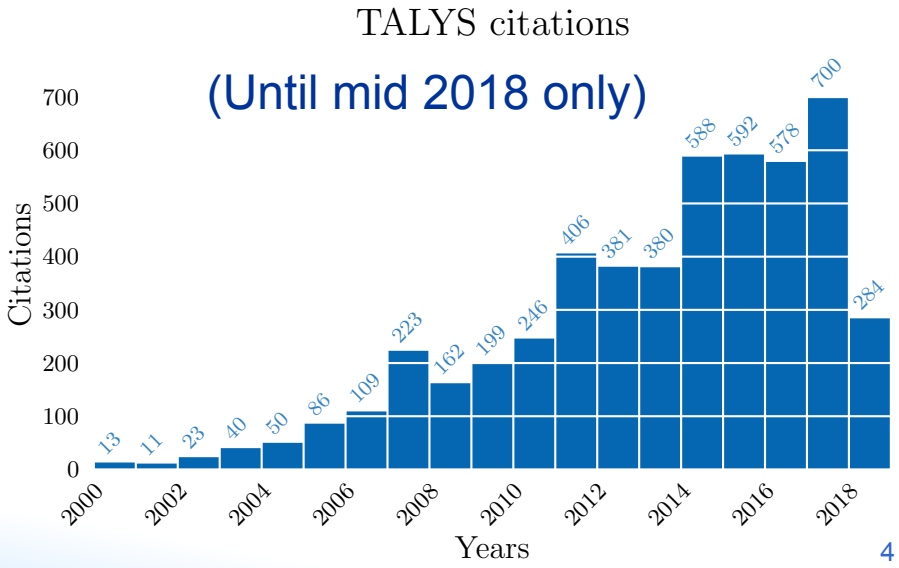
Use of TALYS



Number of TALYS users:
a few thousand

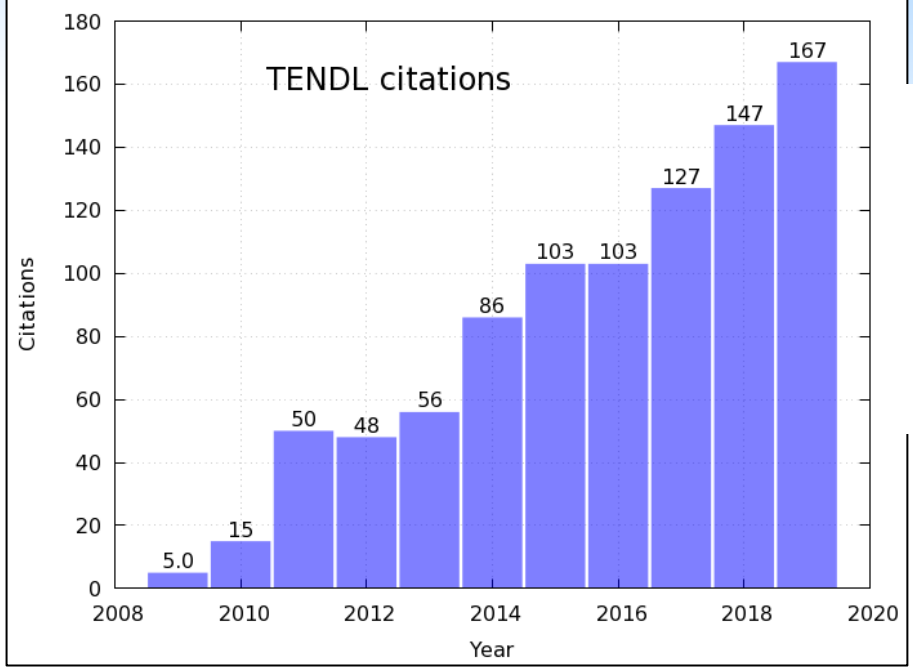
Number of papers citing TALYS:
~ 7000 (as of end 2021)

Somewhat arbitrary distribution over users



TENDL: TALYS Evaluated Nuclear Data Library

- General purpose nuclear reaction data library
- Simultaneous focus on
  - Reproducibility ✓
  - Completeness ✓
  - Quality (ongoing, never enough)
- Heavily based on the TALYS nuclear model code
- Extent:
  - Neutrons, photons, protons, deuterons, tritons, Helium-3, alpha-particles
  - 2813 nuclides (all stable or with half-life > 1 sec.)
  - 0-200 MeV
  - All cross sections and secondary distributions (particle and gamma spectra)
  - UQ with covariance matrices or random distributions
  - A variety of data formats
- TENDL ranges from global TALYS calculations to detailed isotopic evaluations
- TENDL-2021 to be released in December 2021
- https://tendl.web.psi.ch/tendl_2019/tendl2019.html



ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

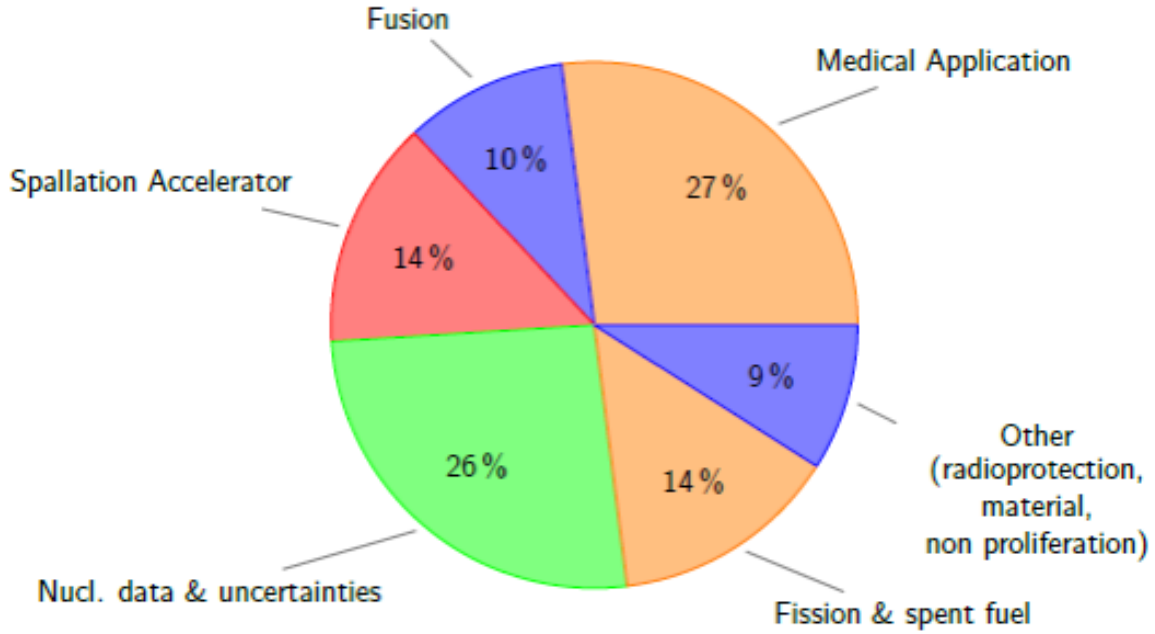
Nuclear Data Sheets

Nuclear Data Sheets 155 (2019) 1–55

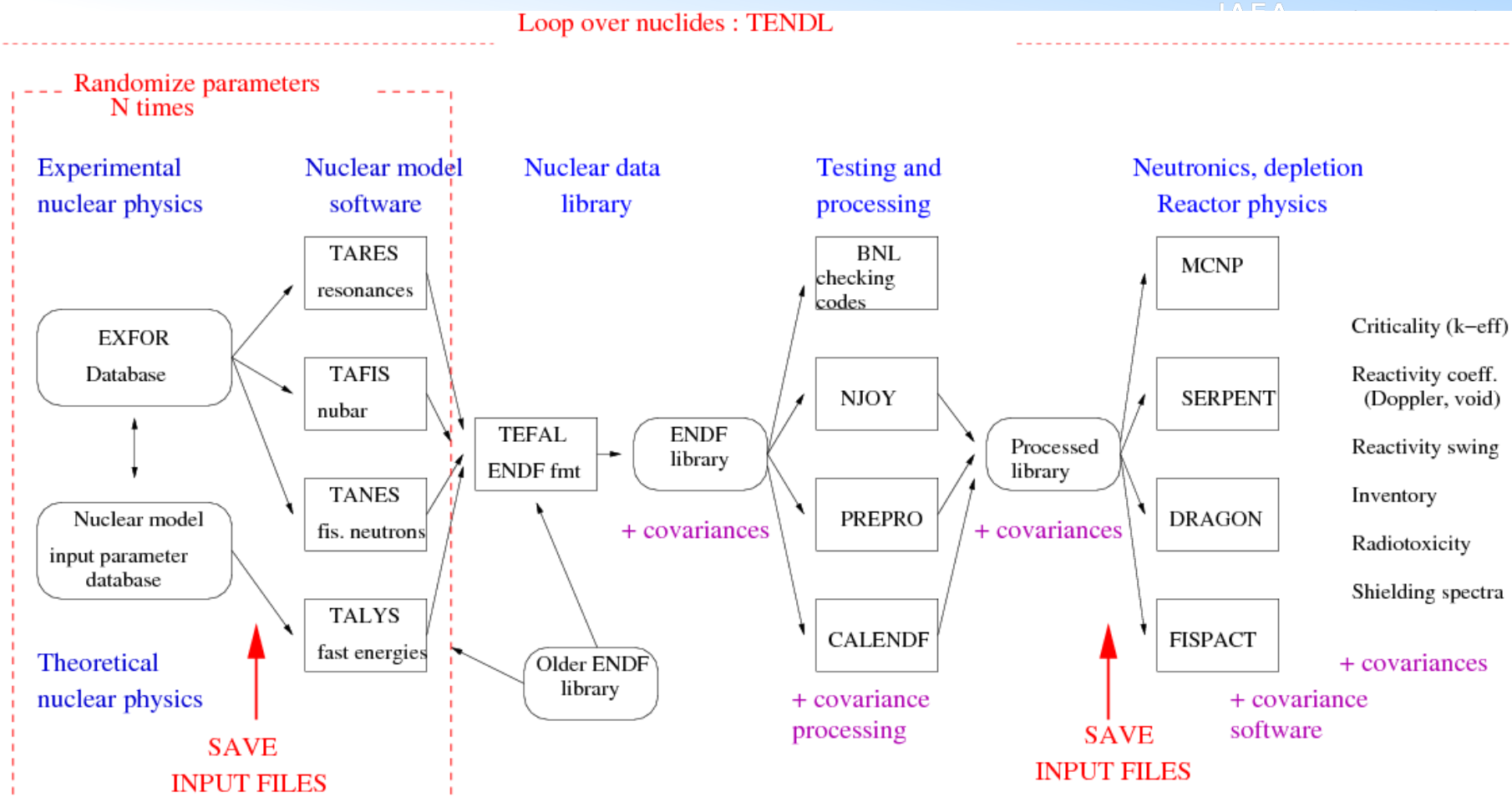
www.elsevier.com/locate/nds

TENDL: Complete Nuclear Data Library for Innovative Nuclear Science and Technology

A.J. Koning,[1,2,*] D. Rochman,[3] J.-Ch. Sublet,[1] N. Dzysiuk,[4,5] M. Fleming,[6,7] and S. van der Marck[4]



TENDL: A nuclear data pipeline since 2009



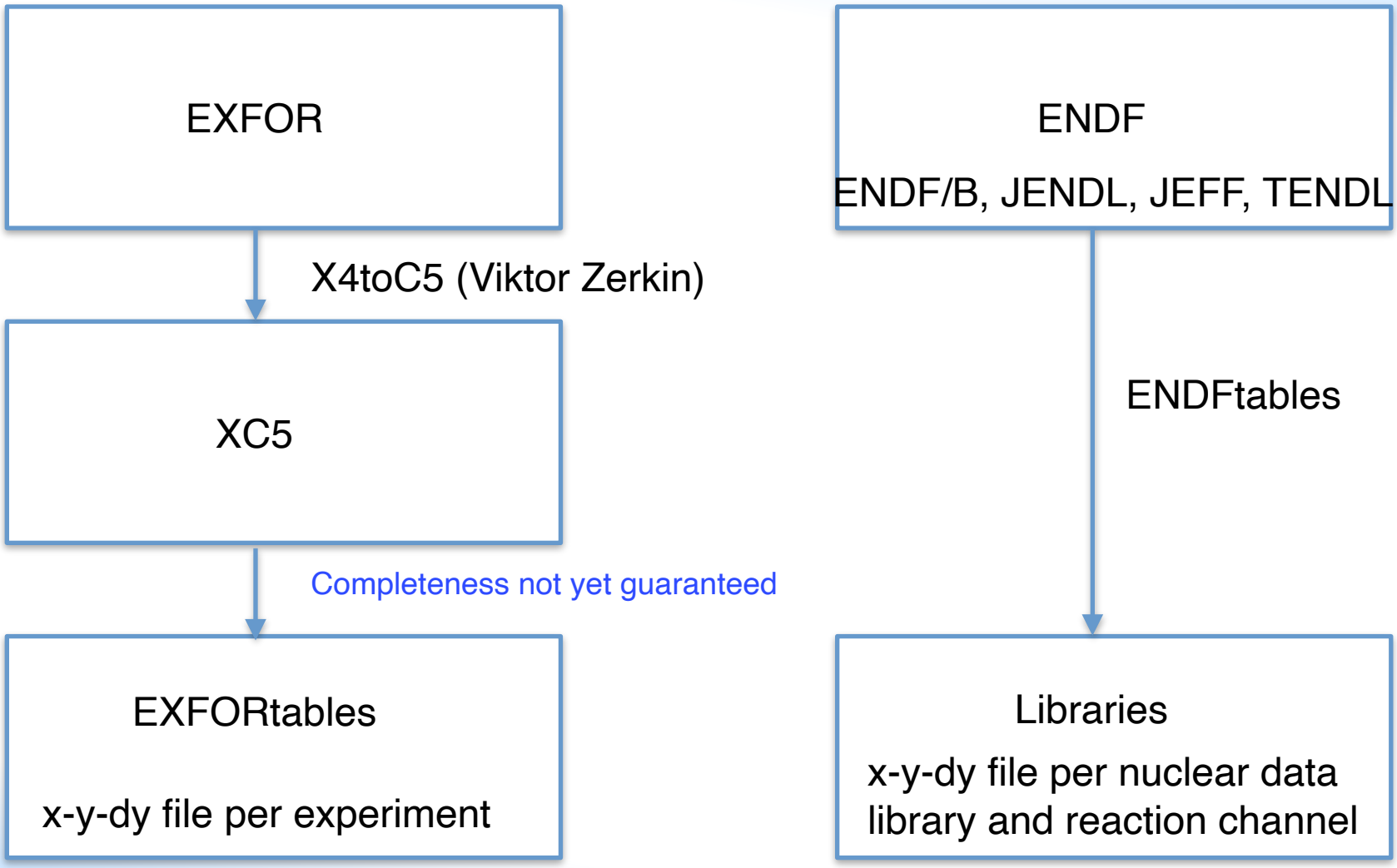
Once this system (**T6**) works, only the input files (= “the evaluation”) are important

Reproducibility

TENDL paradigm for nuclear data evaluation

- TALYS/TENDL relies strongly on automation, global model improvement, efficient comparison with data for all nuclides and reactions
- All historical nuclear data of importance:
  - EXFOR
  - Other experimental data compilations/evaluations(EGAF, Resonance Atlas etc.)
  - Existing nuclear data libraries (ENDF/B, etc)
  - ….need to be available on the spot, with command-line access, for massive and efficient plotting and manipulation into better nuclear data libraries, with the help of a nuclear model code
- WPEC SG50: Developing an Automatically Readable, Comprehensive, and Curated Experimental Reaction Database (derived from EXFOR)
- Exforcism: flagging evil data in EXFOR (but not drive them out)

Decrypting EXFOR and ENDF



`libraries/a/F019/tendl.2019/tables/XS/a-F019-MT004.tendl.2019`

`exfor/a/F019/XS/004/a-F019-MT004-Peters-C0500002.2016`

TALYS-Related Software and Databases

TALYS and the TALYS-related packages are open source software and datasets (GPL License) for the simulation of nuclear reactions.

Coming soon, still available here

TALYS

Arjan Koning, Stephane Hilaire, Stephane Goriely

Nuclear reaction model code.

Download TALYS-1.95
Download previous versions
Read Tutorial

Created at NRG CEA ULB UNIVERSITÉ LIBRE DE BRUXELLES IAEA

EXFORTABLES

Arjan Koning

Experimental nuclear reaction database based on EXFOR.

Download EXFORTABLES-1.0
Read Tutorial

RESONANCETABLES

Arjan Koning, Dimitri Rochman

Database for thermal cross sections, MACS and average resonance parameters.

Download RESONANCETABLES-1.0
Read Tutorial

Created at IAEA PSI

ENDFTABLES

Arjan Koning

Code to translate ENDF nuclear data libraries into tabular format.

Download ENDFTABLES-1.0
Read Tutorial (Chapter 2)

Libraries-2020

Arjan Koning

Evaluated nuclear data libraries and EXFOR in tabular format.

Libraries-2020 [15GB]
Read Tutorial (Chapter 3)

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nds.iaea.org/talys

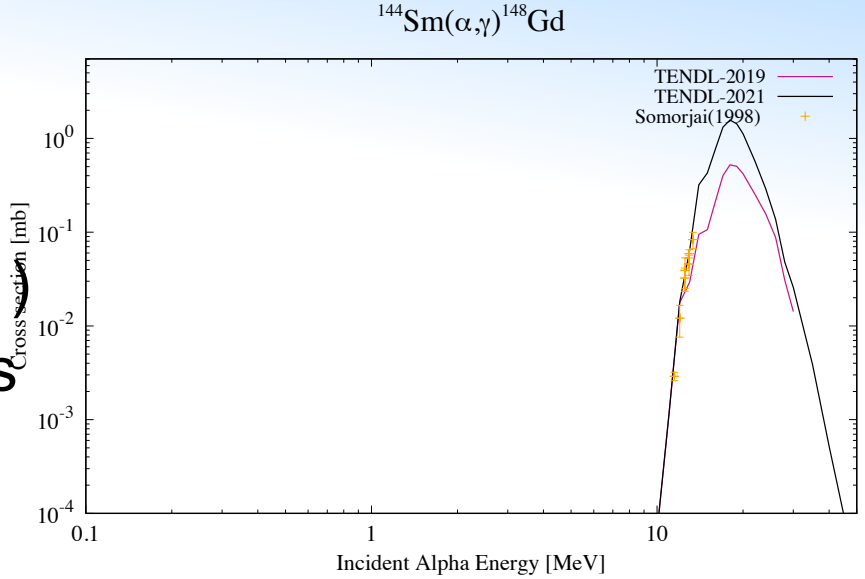
TASMAN, TEFAL, and Tools for TALYS (“T6”) soon to follow

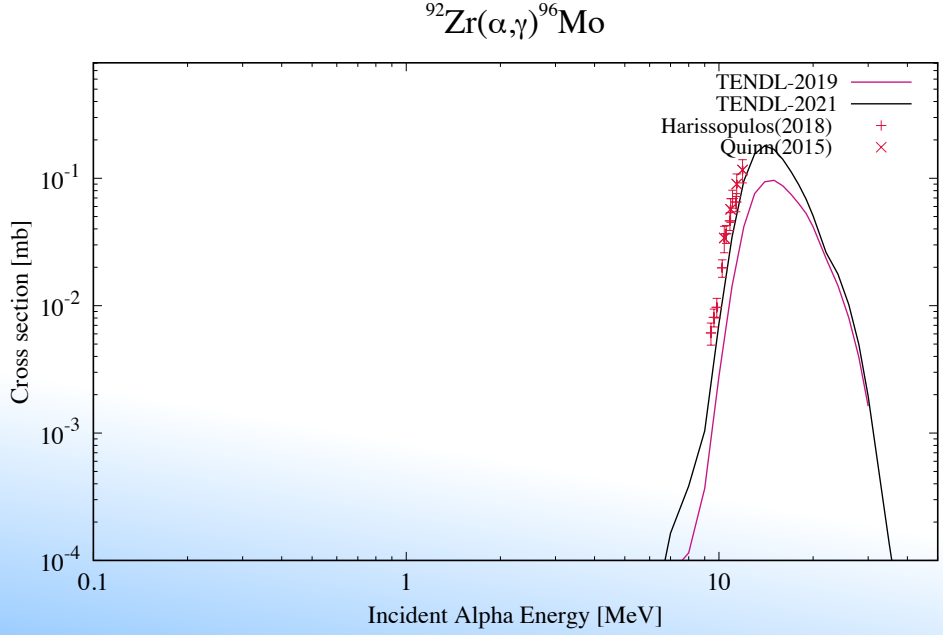
Models specific for α -induced reactions

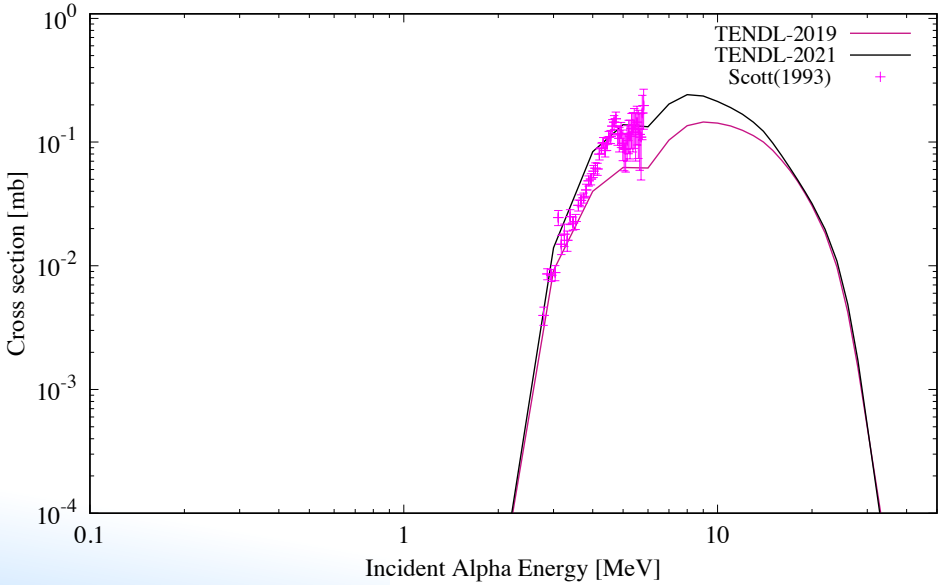
- Optical model potential:
  - α : Avrigeanu 2014
  - Outgoing n, p: Koning-Delaroche 2003
- Pre-equilibrium and direct reactions:
  - Two-component exciton model, Koning-Duijvestijn 2005
  - Stripping reaction: Kalbach model 2005
- TENDL-2021:
  - Global increase of adjustable parameter for stripping for (α ,n) and (α ,p)
  - Improvement in binning of Hauser-Feshbach model (correction found by Sandor Sudar)
- All following results are from global calculations

‘Competing’ channel: (α , γ)

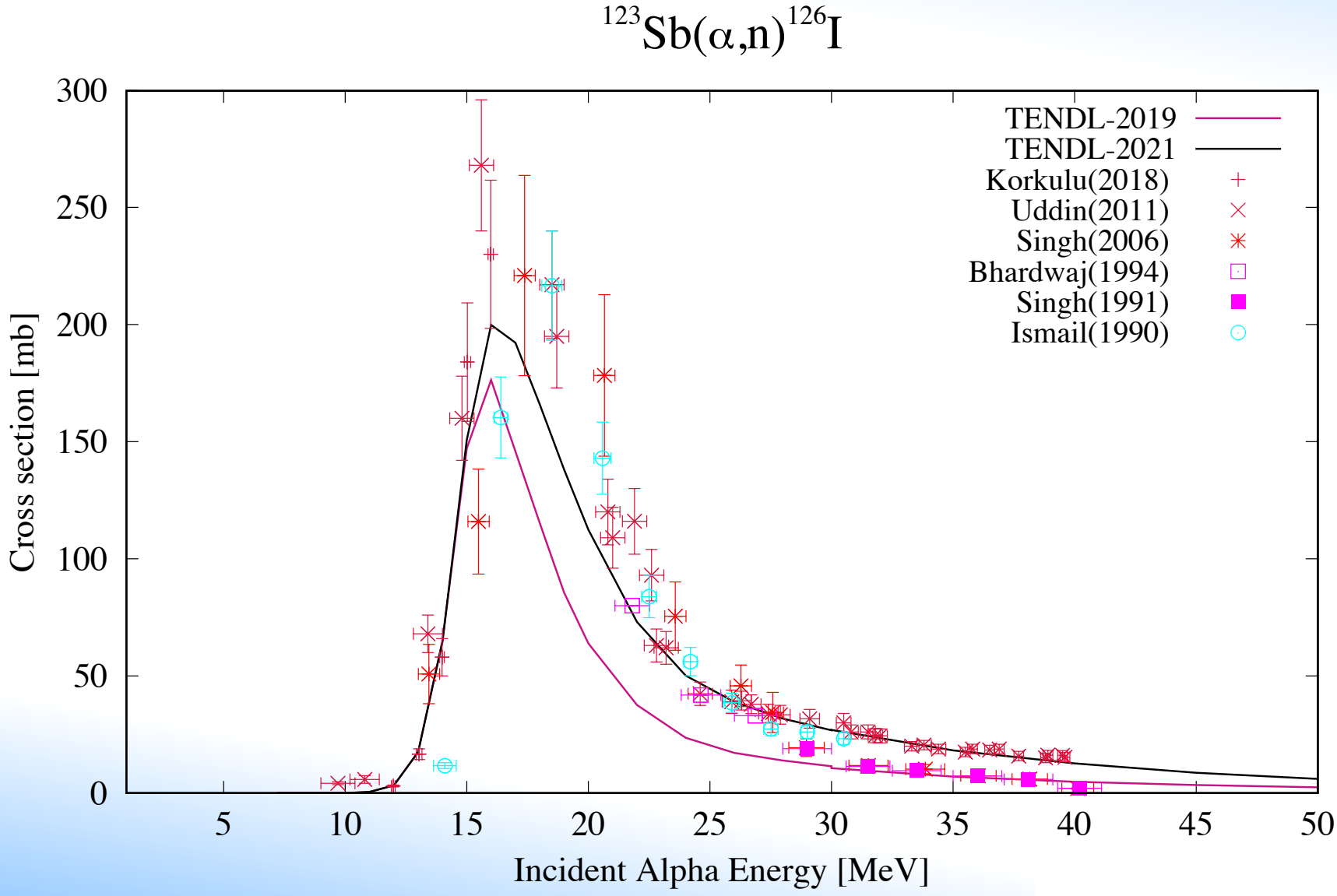
- New photon strength functions (Plujko & Goriely), SMLO, give better gamma-related data for all reaction channels, including (α ,γ)
- CRP on photon strength functions and photonuclear data, Dimitriou et al (IAEA 2019)



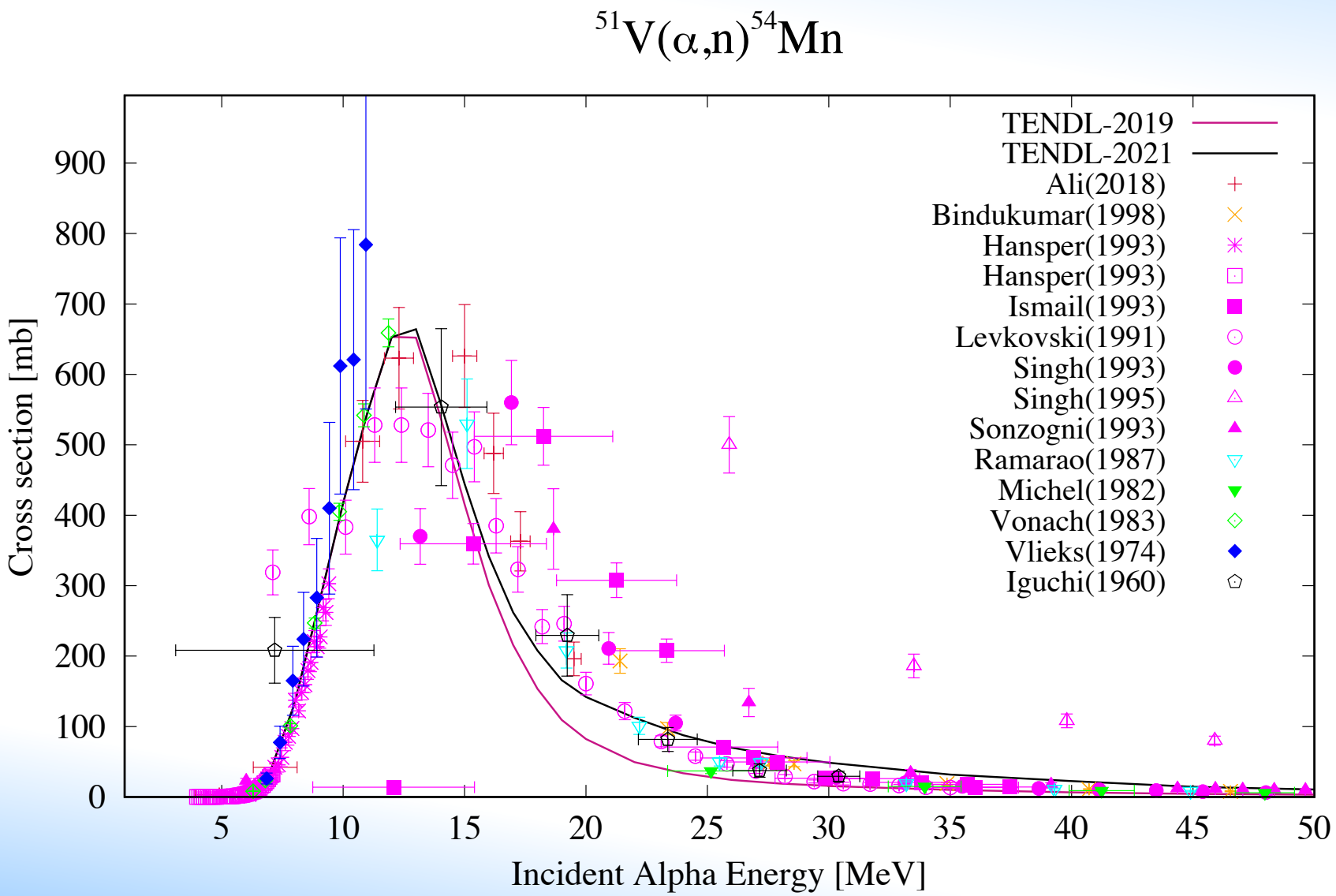




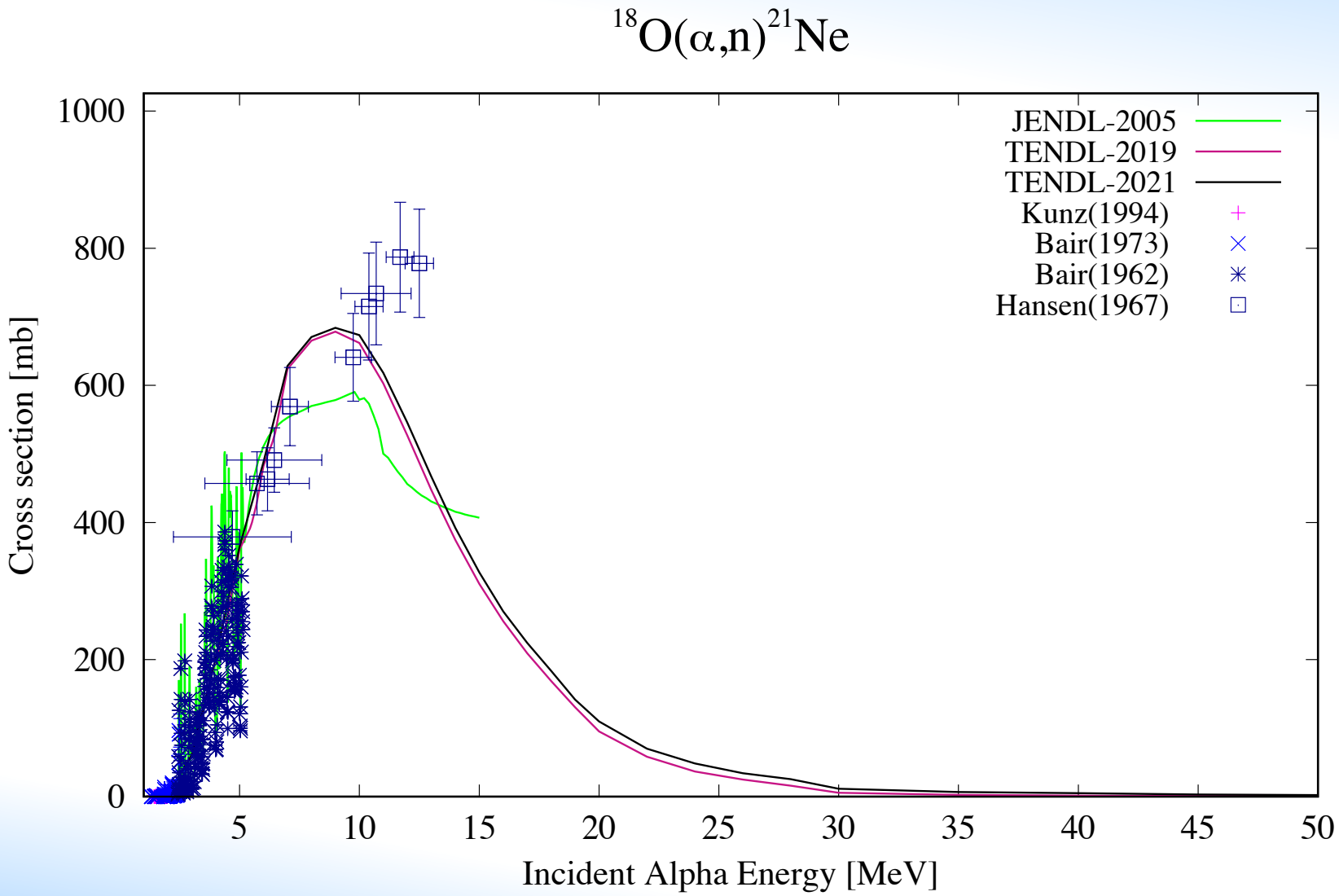
There are 93 (α ,n) plots like this



Some Exforcism required?



TALYS does not provide resonance structure



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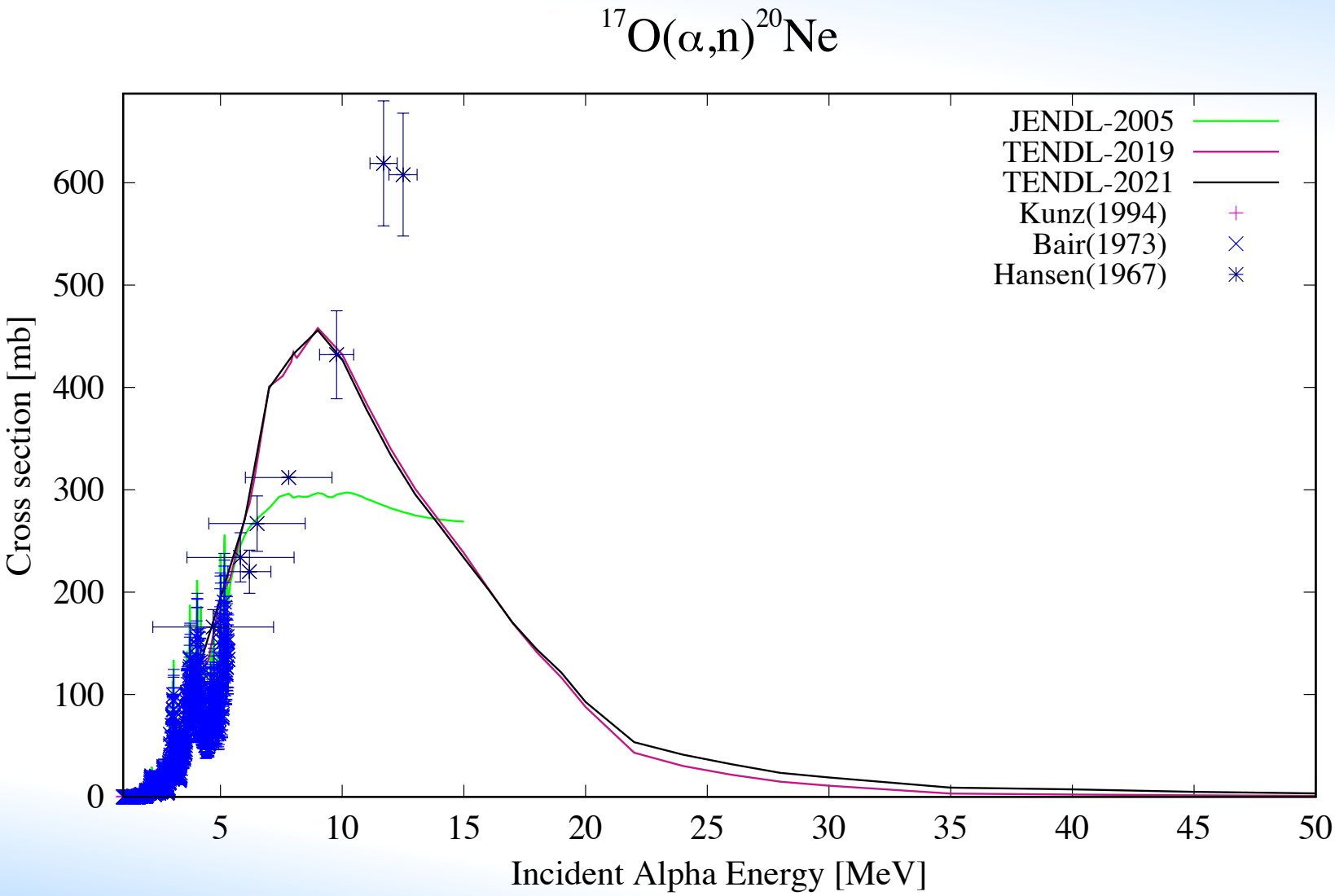
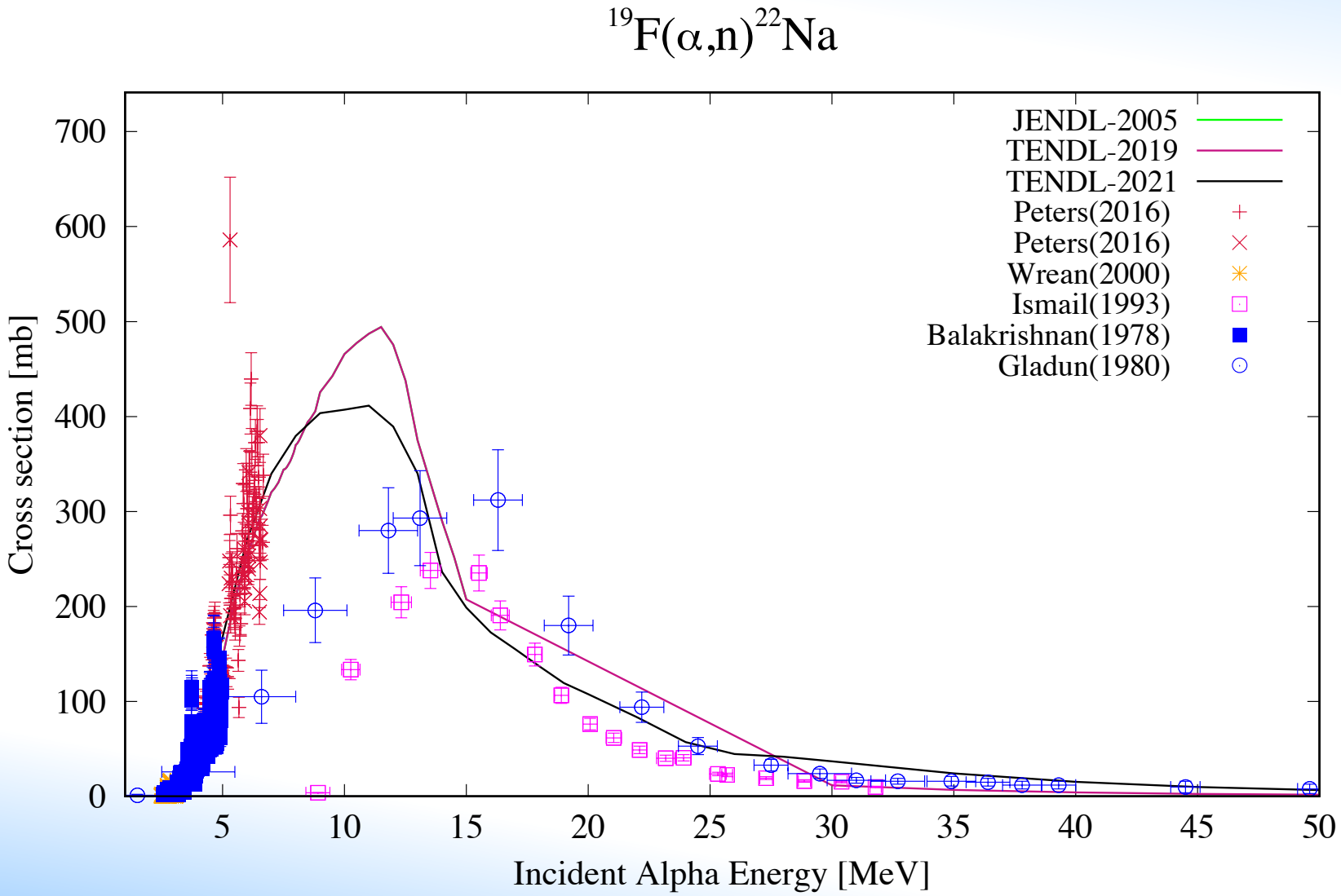
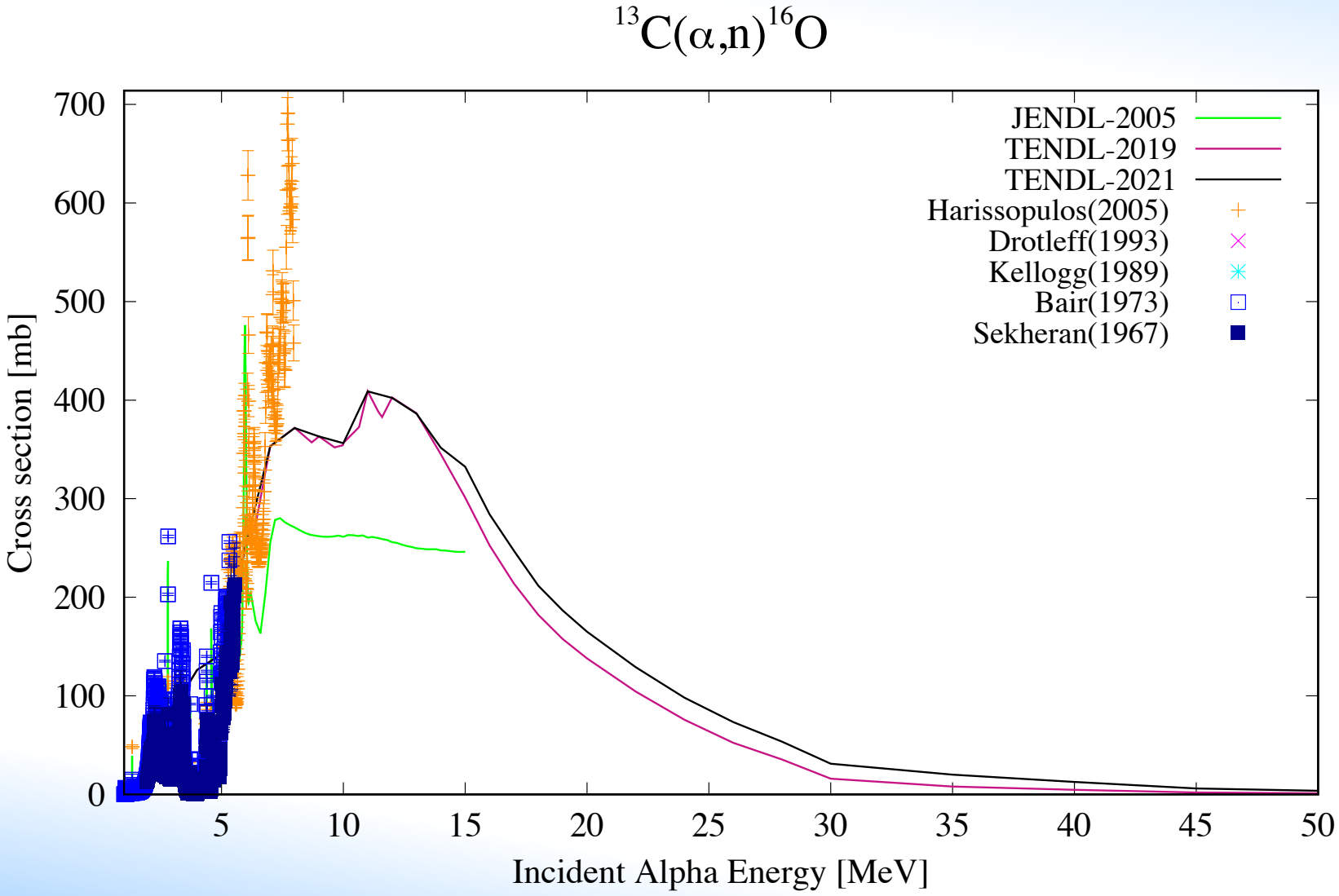
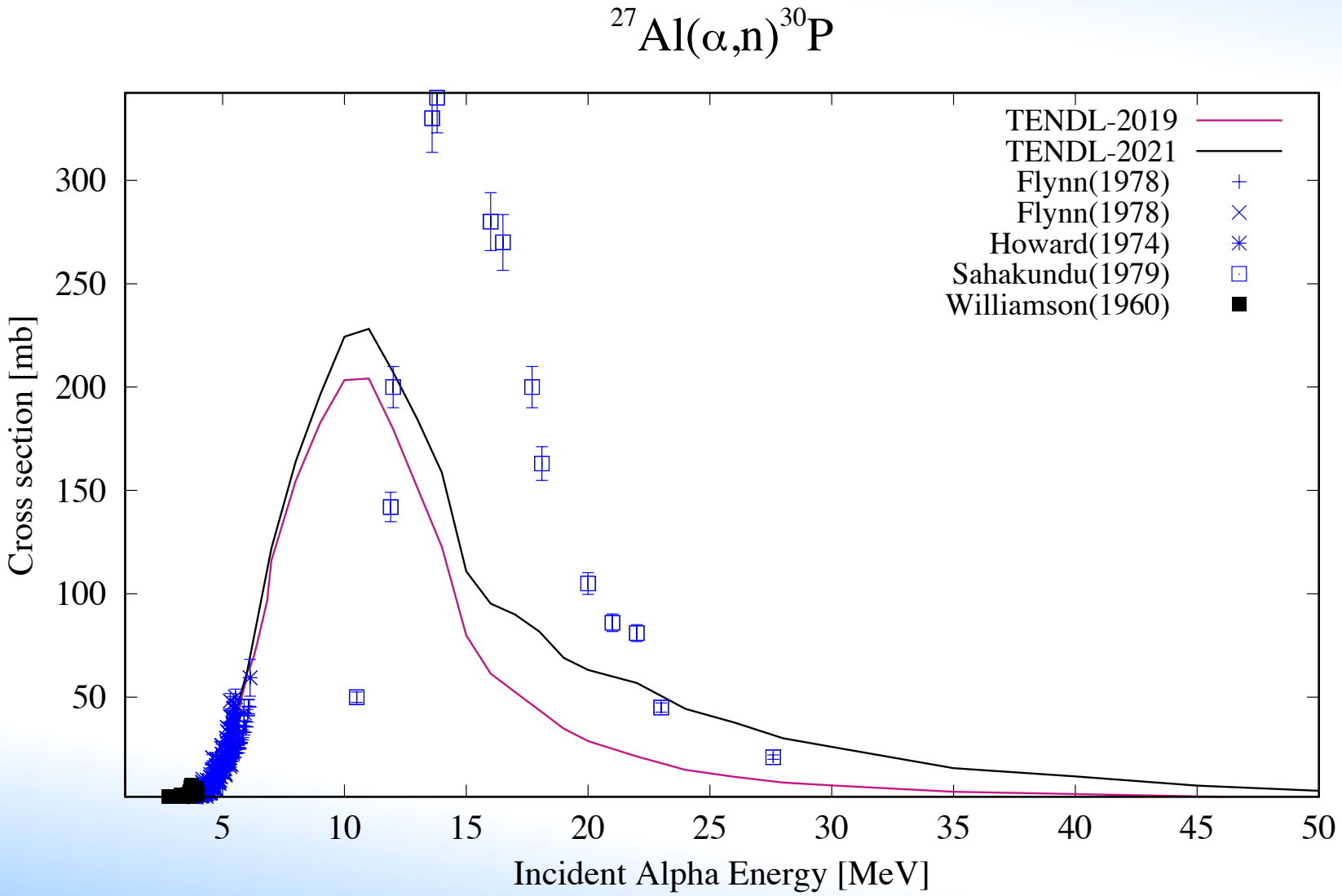


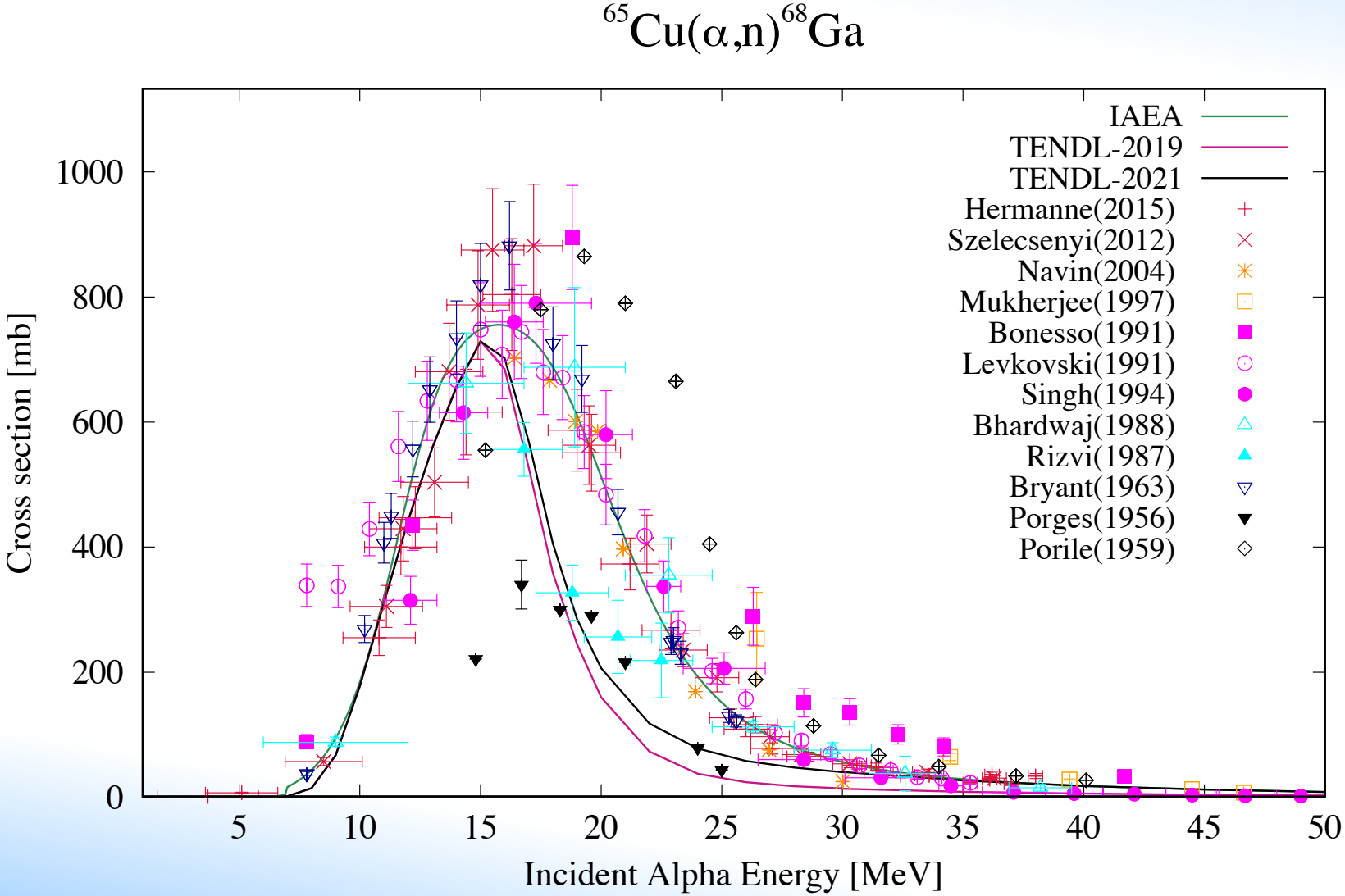




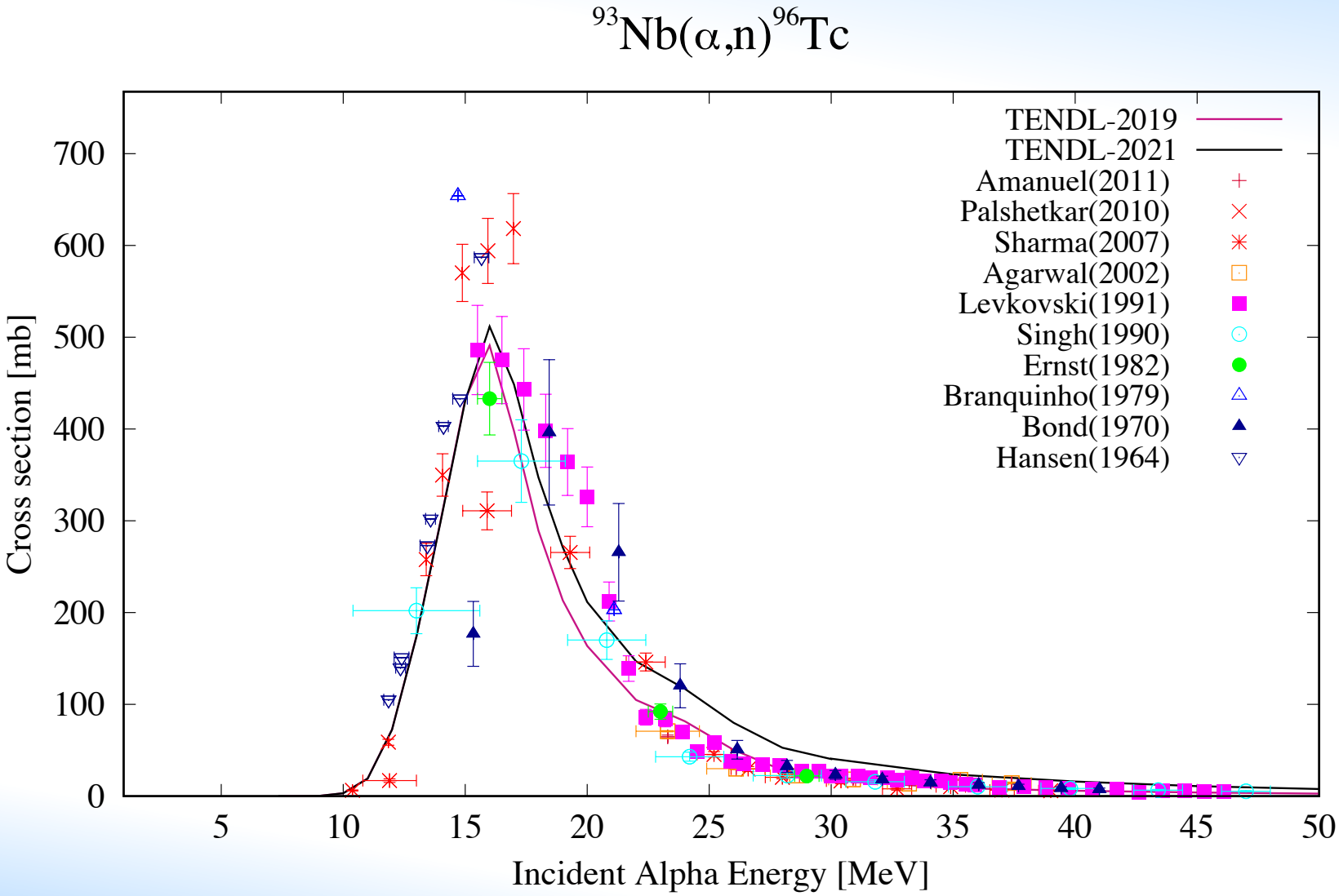
Another suspicious data set?

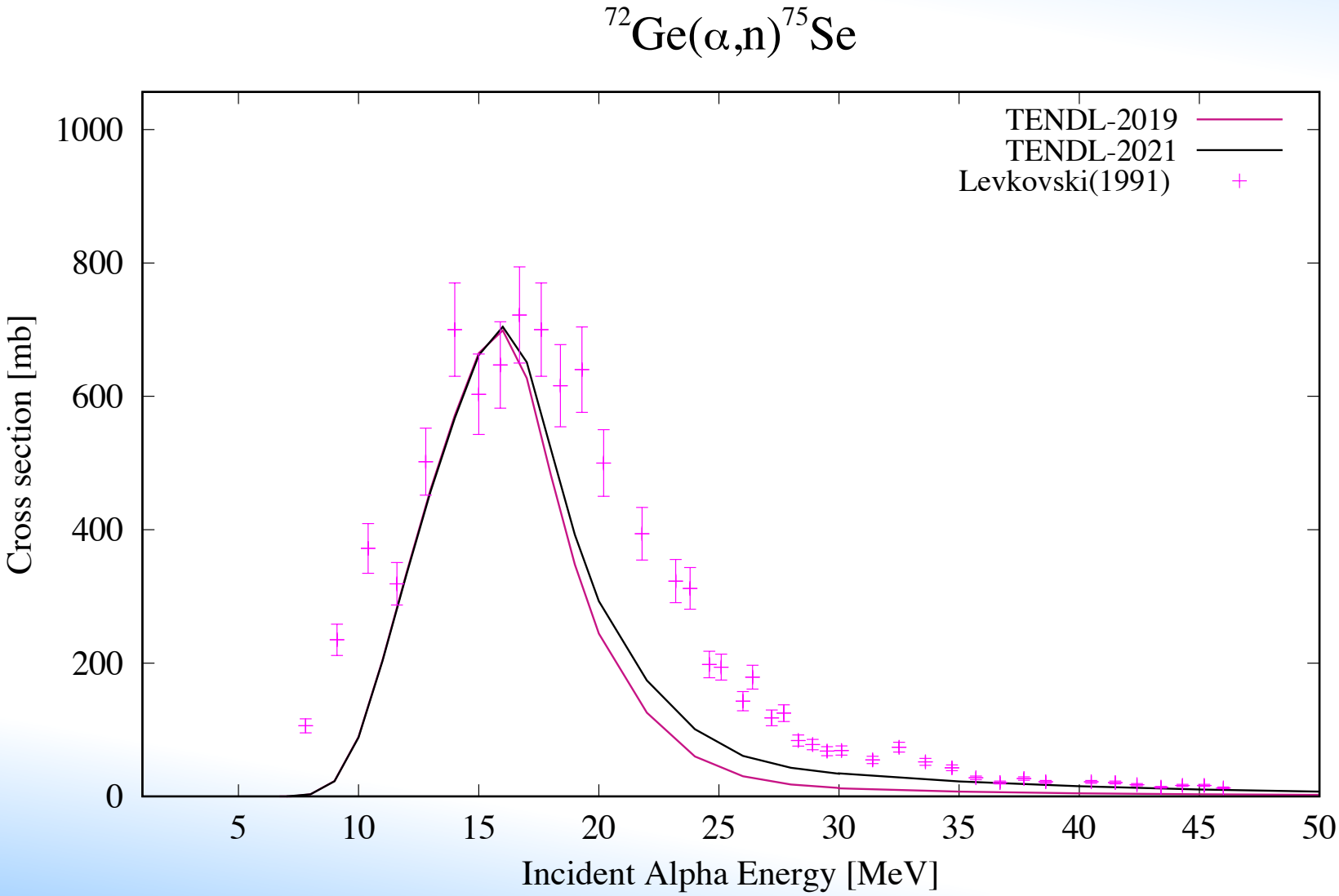


(α , n) route for medical isotopes



Sometimes TENDL-2019 better than TENDL-2021?





Also consider nds.iaea.org/dataexplorer/

IAEA International Atomic Energy Agency

LIBRARIES-2021 Data Explorer

Tips

Cross Section | Multiple Cross Sections (Libs. only) | Residual Production Cross Section | Fission Yield

Cross Sections from ENDFTABLES and EXFORTABLES

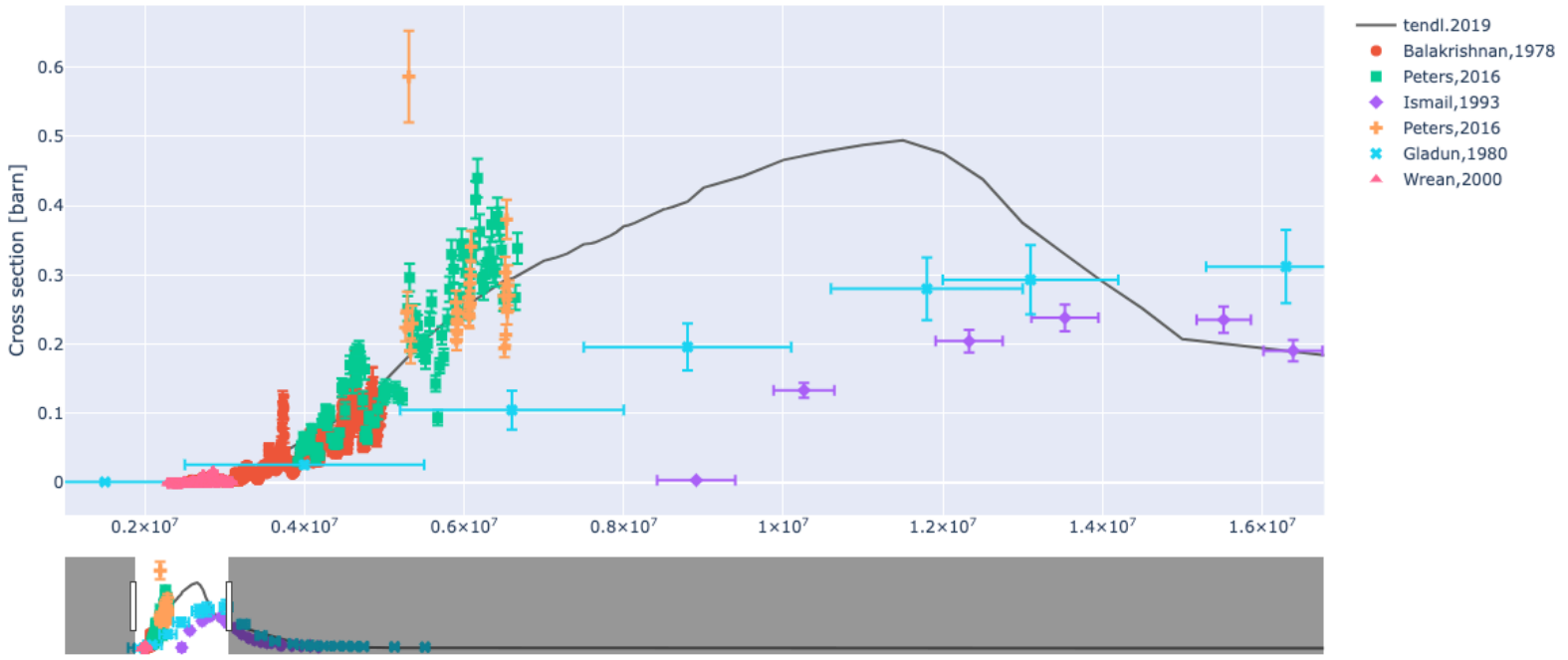
Target element: F

Target mass: 19

Reaction: a,n

F019(a,n), found 6 experimental dataset(s).

Groupwise (Use 1102 groupwise data if exists) X: Linear Log Y: Linear Log



Summary

- TENDL-2021 contains a complete alpha nuclear reaction library
  - Global predictive power of TALYS for (α ,n) cross sections: 20-40%
    - Probably good enough for scoping studies in various applications
    - Not enough for certain applications
  - All secondary spectra, gamma-production etc also included, covariance matrices. ENDF-6 or other formats.
- Possible further improvement
  - Improvement of TALYS global models for optical model, level density, pre-equilibrium
  - Fitting of TALYS to those nuclides where experimental data exists
    - improve central values and reduce uncertainty of the evaluation - then decide if application requires smaller uncertainties (= new measurements)
    - use adjustable optical model, level density and pre-equilibrium parameters
  - Blend in JENDL/AN for those nuclides (F, O) where non-TALYS resonance structures exist. Techniques: model defects, Gaussian processes etc.

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Thank you!