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60 Years

Atoms for Peace and Development

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

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

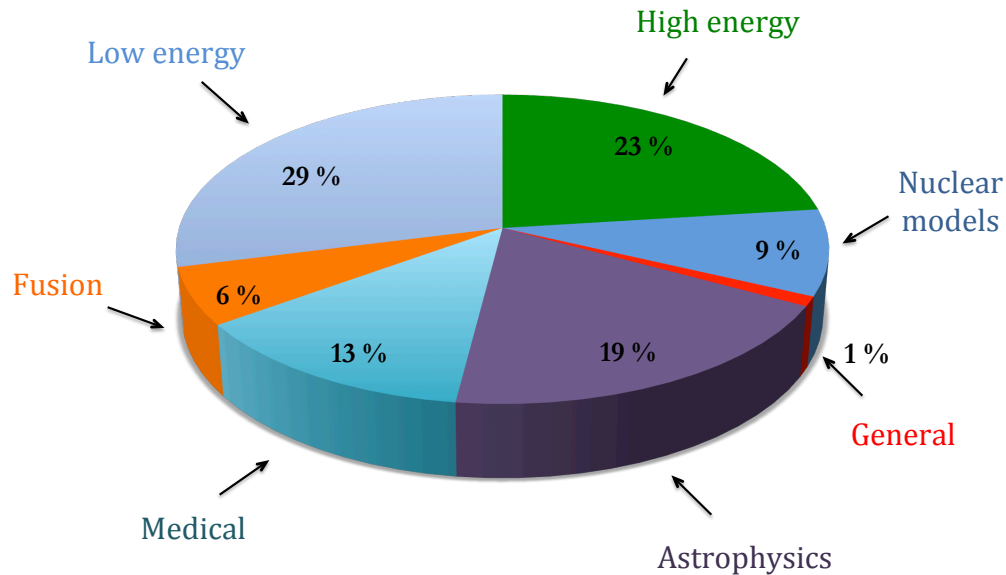
Contents

- 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

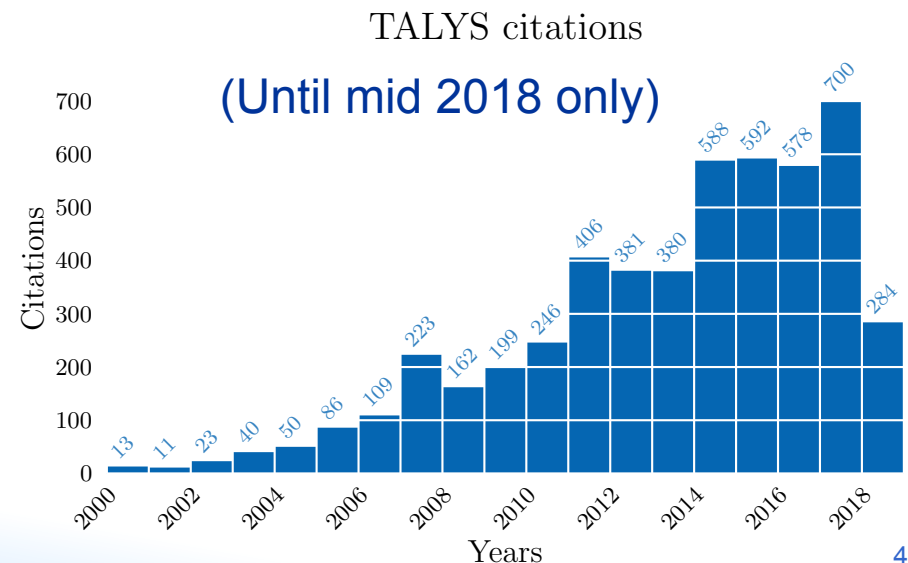
Use of TALYS



Somewhat arbitrary distribution over users

Number of TALYS users:
a few thousand

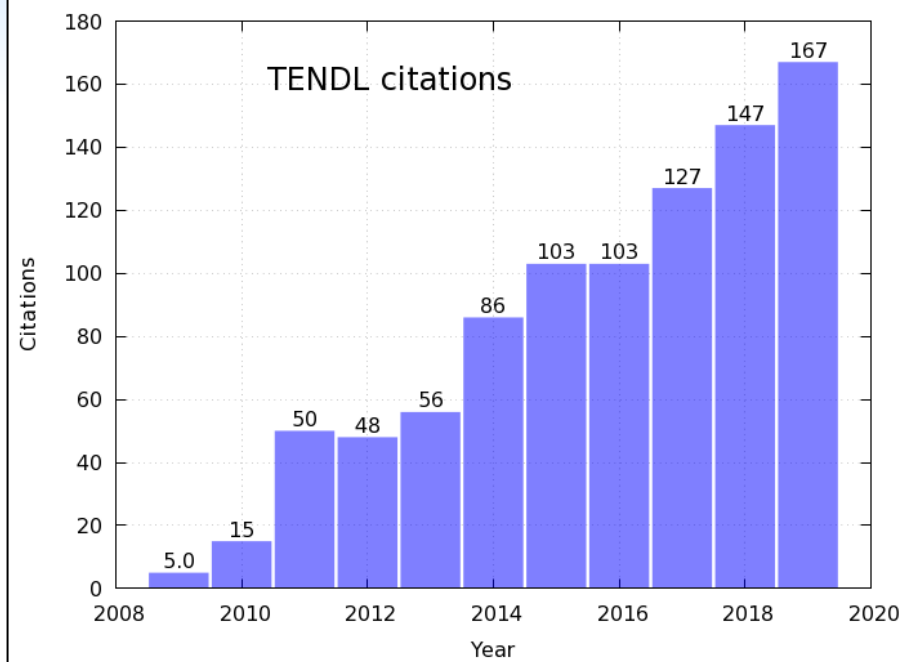
Number of papers citing TALYS:
~ 7000 (as of end 2021)



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



Available online at www.sciencedirect.com

ScienceDirect

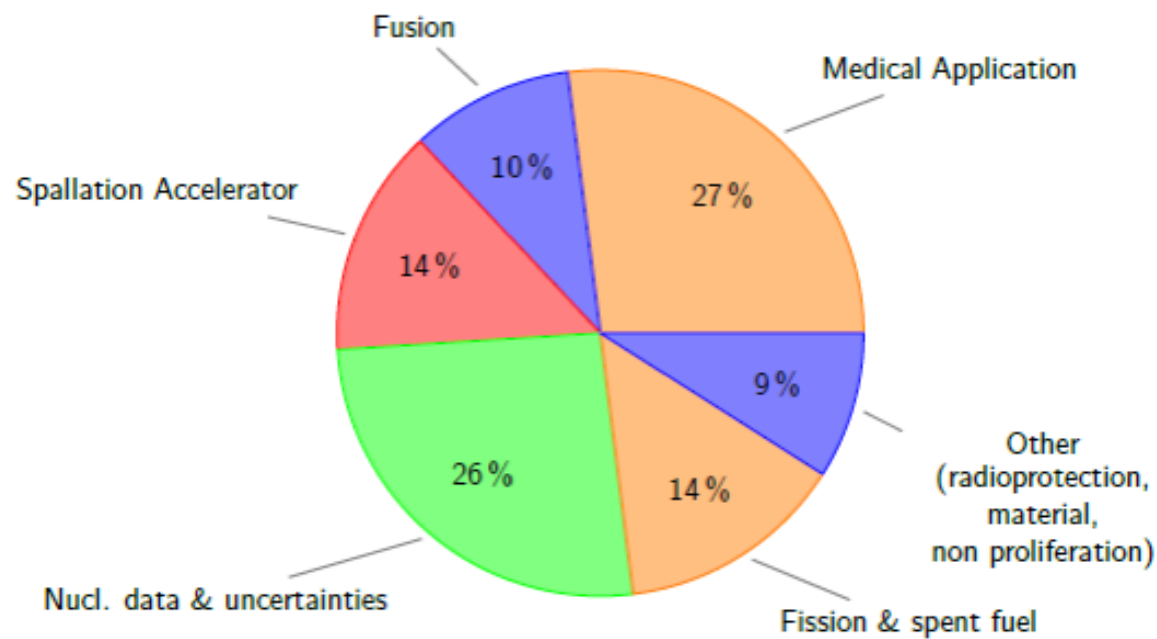
Nuclear Data Sheets 155 (2019) 1–55

**Nuclear Data
Sheets**

www.elsevier.com/locate/nds

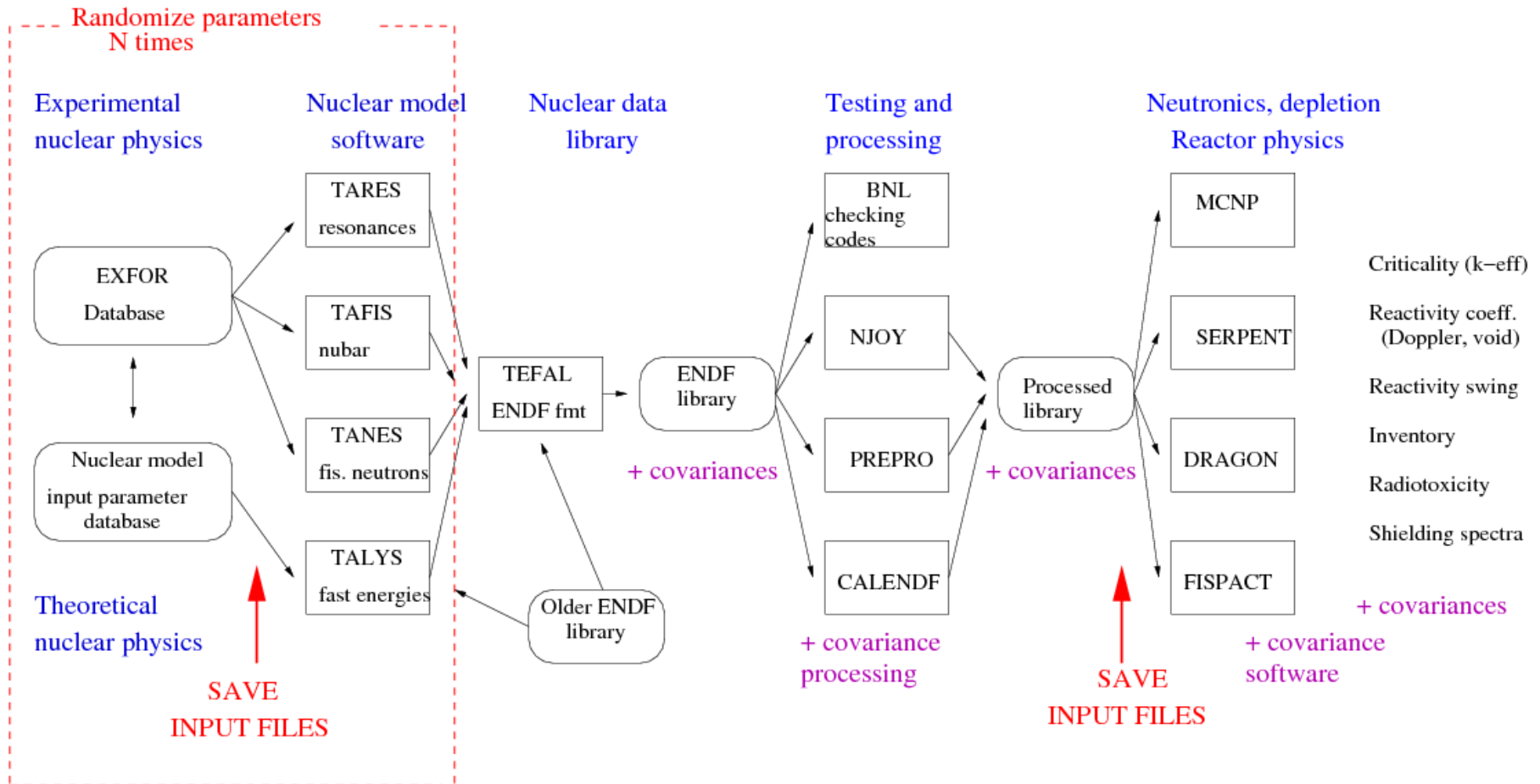
TENDL: Complete Nuclear Data Library for Innovative Nuclear Science and Technology

A.J. Koning,^{1,2,*} D. Rochman,³ J.-Ch. Sublet,¹ N. Dzysiuk,^{4,5} M. Fleming,^{6,7} and S. van der Marck⁴



TENDL: A nuclear data pipeline since 2009

Loop over nuclides : TENDL



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

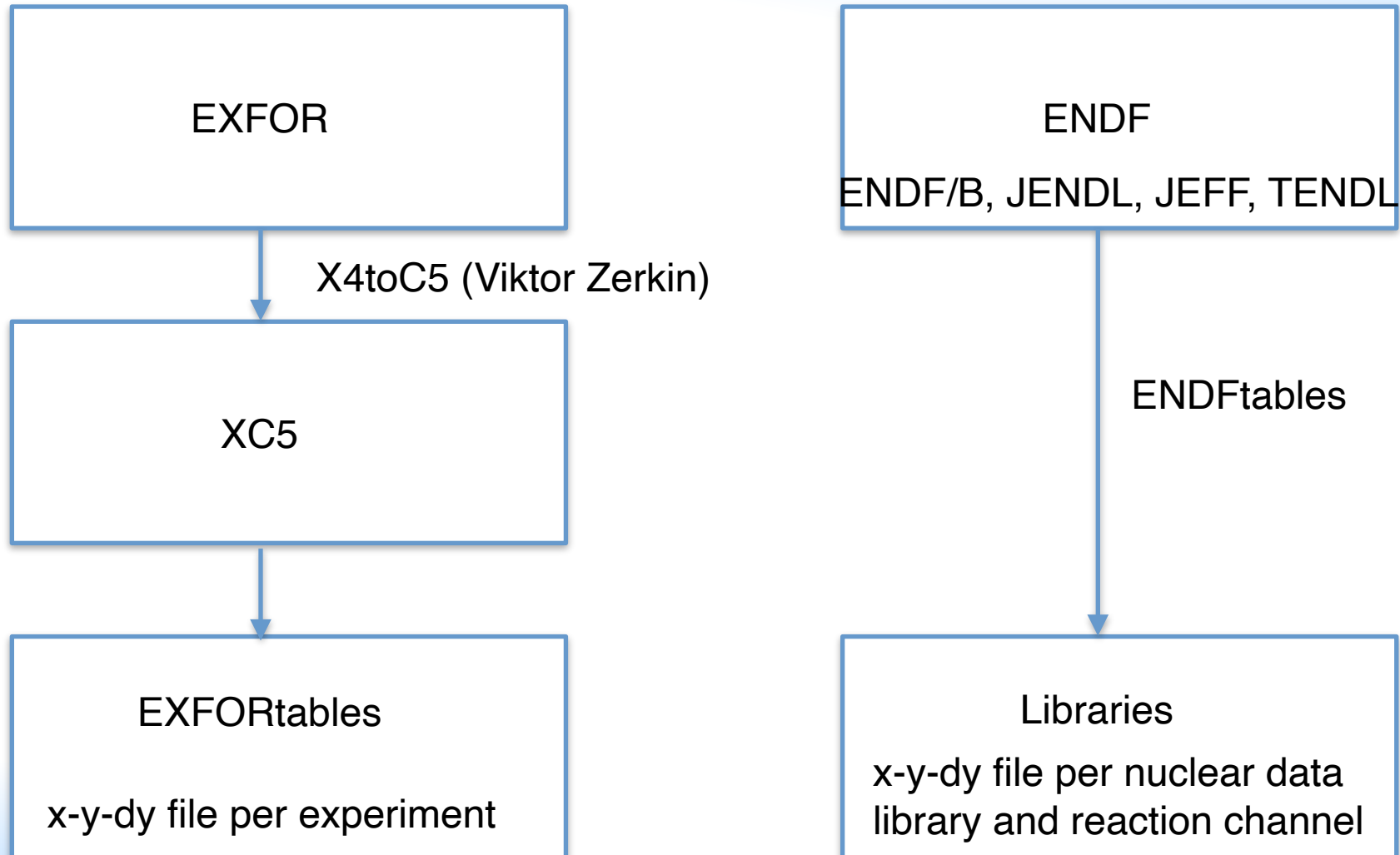
Reproducibility

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.

nds.iaea.org/talys

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

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    UNIVERSITE
LIBRE
DE BRUXELLES  IAEA
International Atomic Energy Agency

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
International Atomic Energy Agency Paul Scherrer Institut

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)

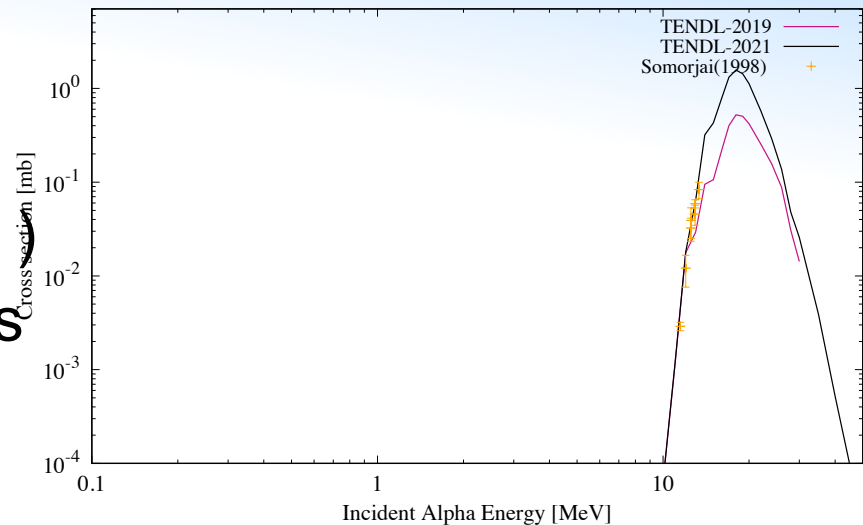
Models specific for α -induced reactions

- 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

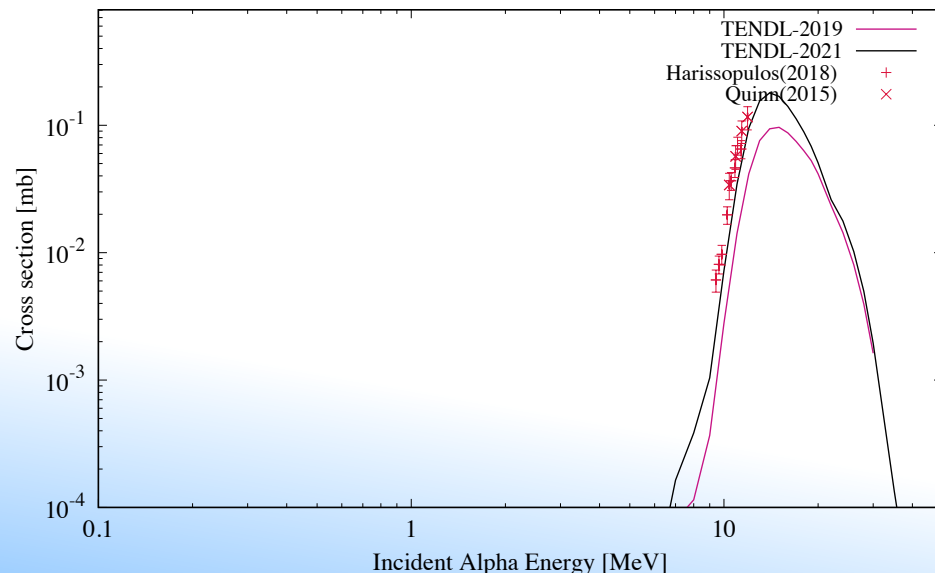
'Competing' channel: (α , γ)

- 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)

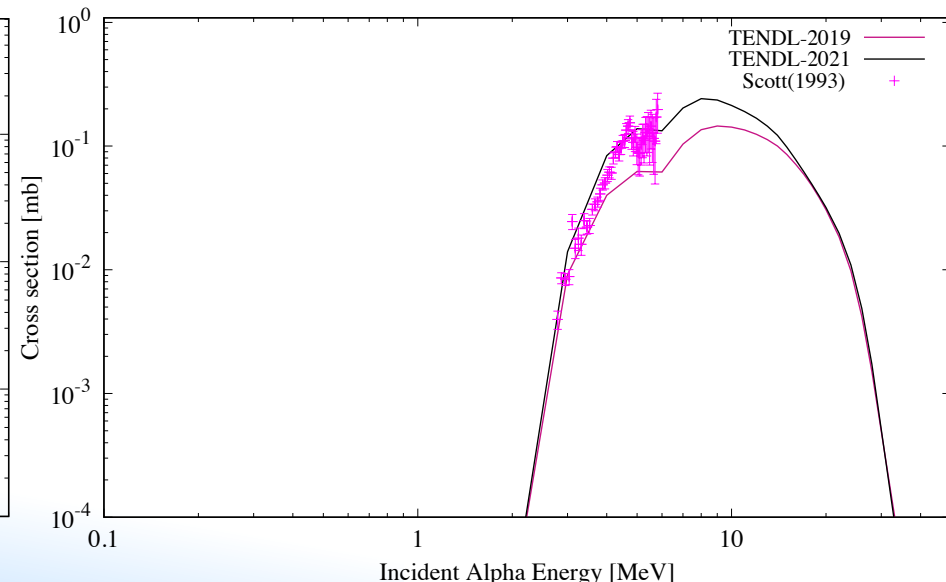
$^{144}\text{Sm}(\alpha,\gamma)^{148}\text{Gd}$



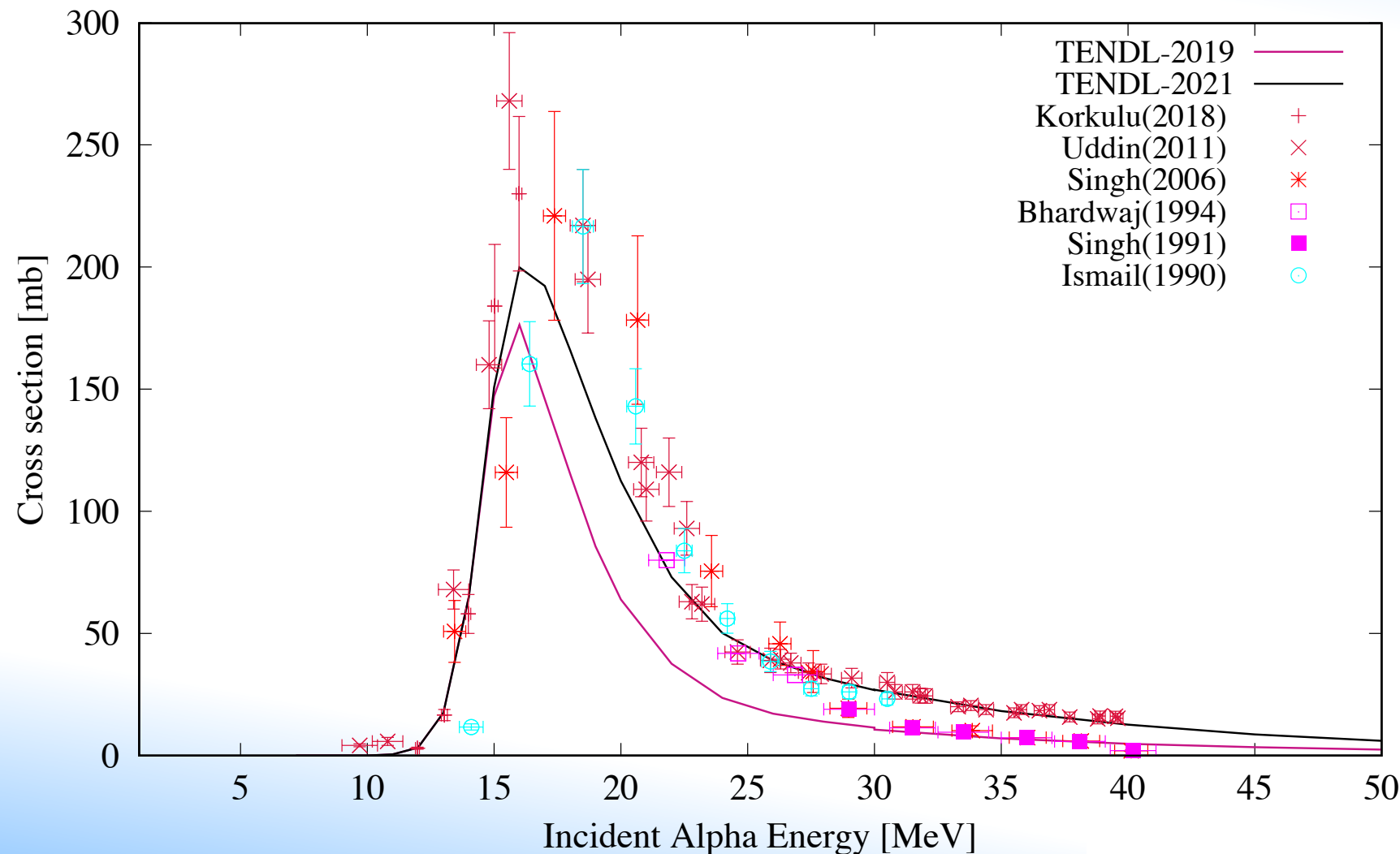
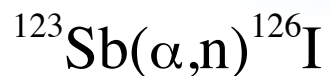
$^{92}\text{Zr}(\alpha,\gamma)^{96}\text{Mo}$



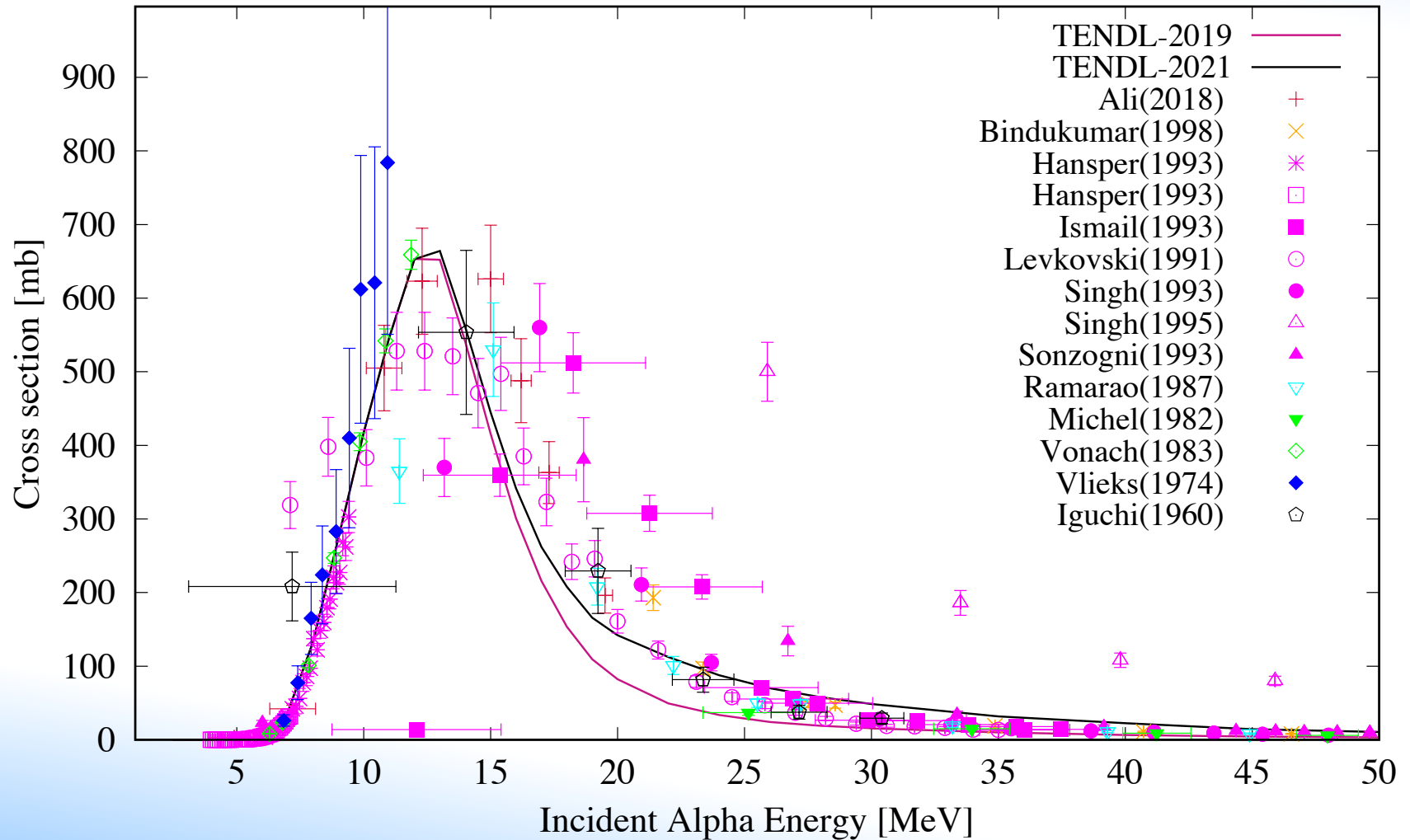
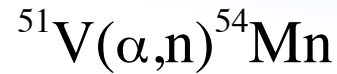
$^{34}\text{S}(\alpha,\gamma)^{38}\text{Ar}$



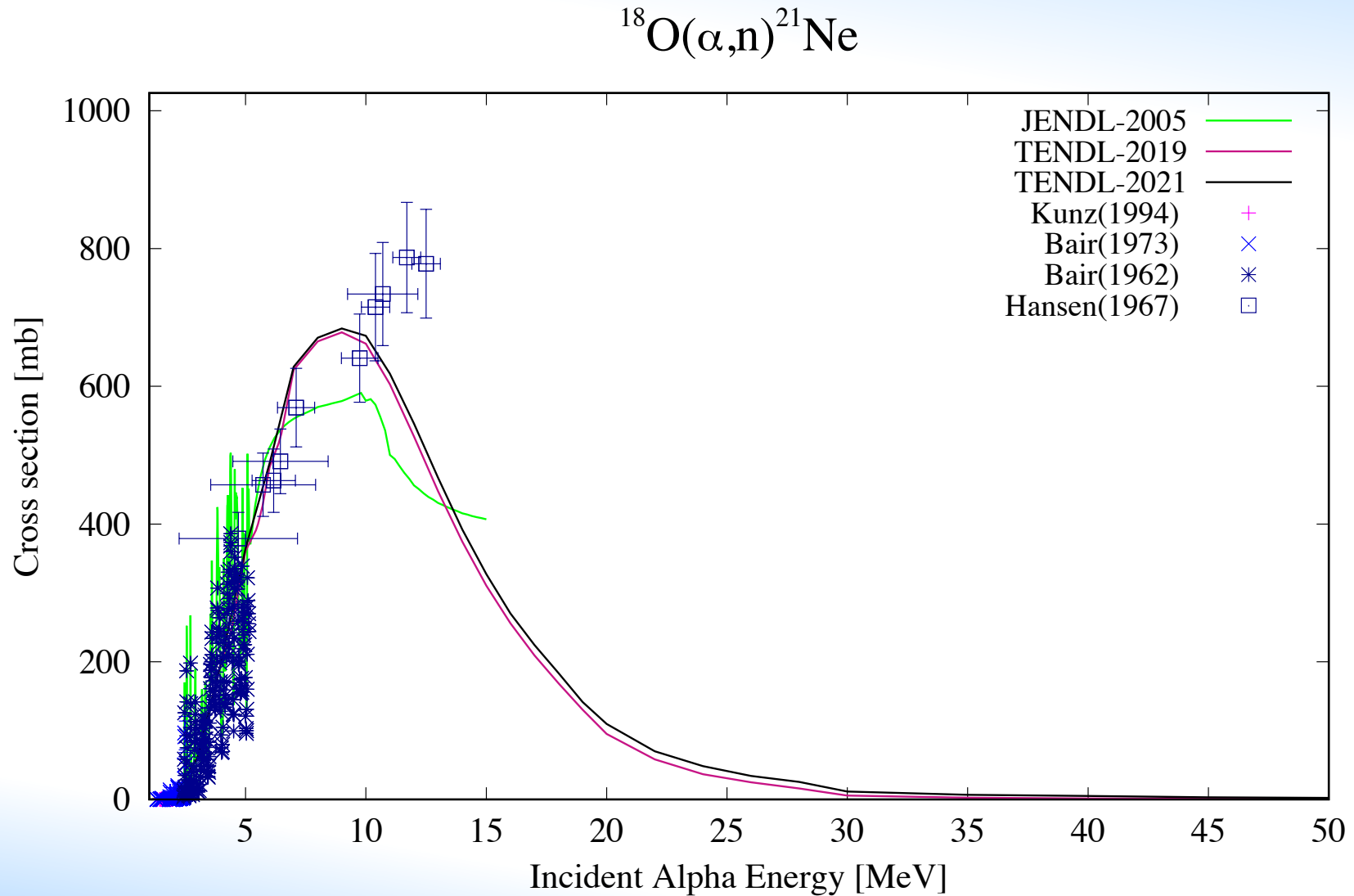
There are 93 (α ,n) plots like this



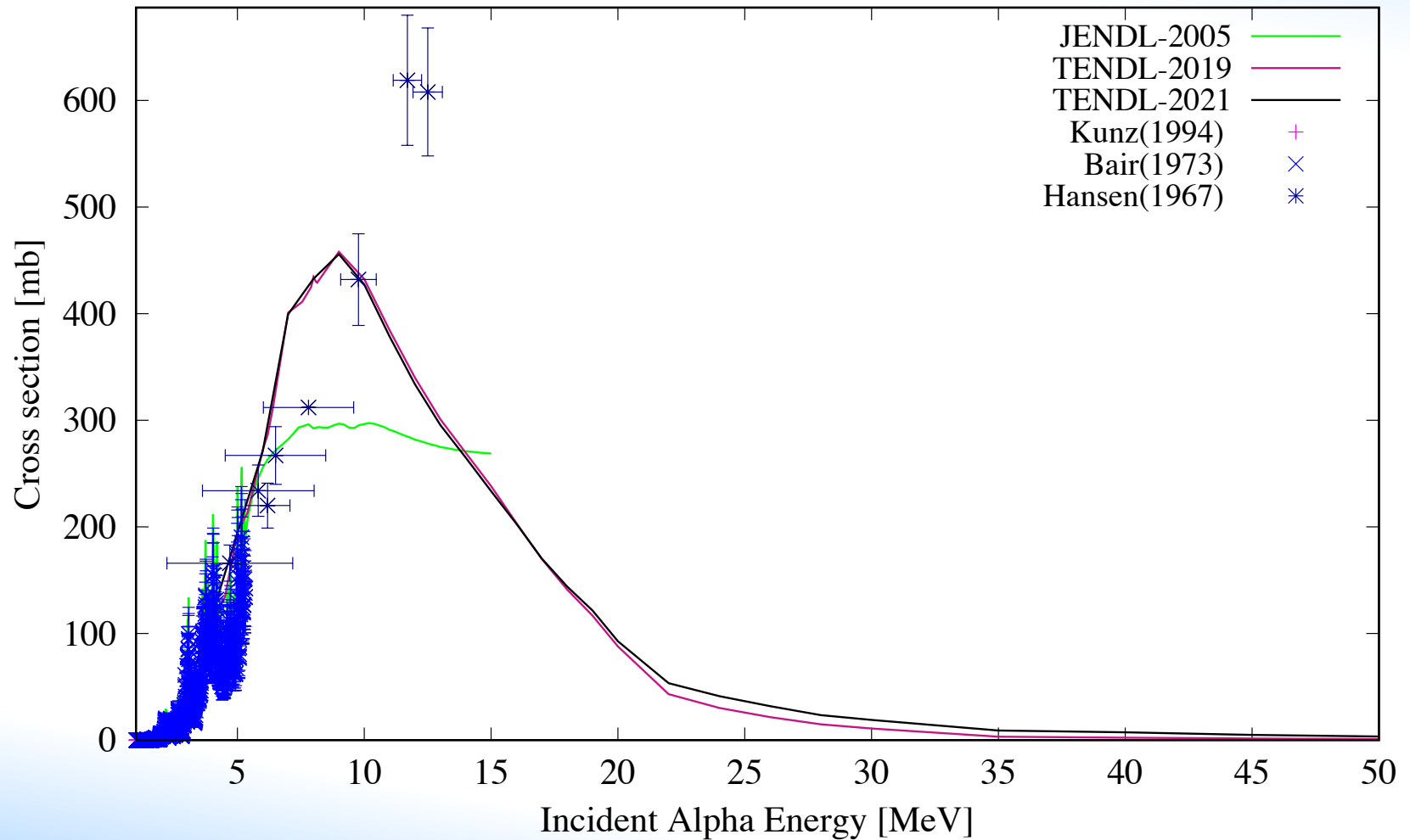
Some Exorcism required?

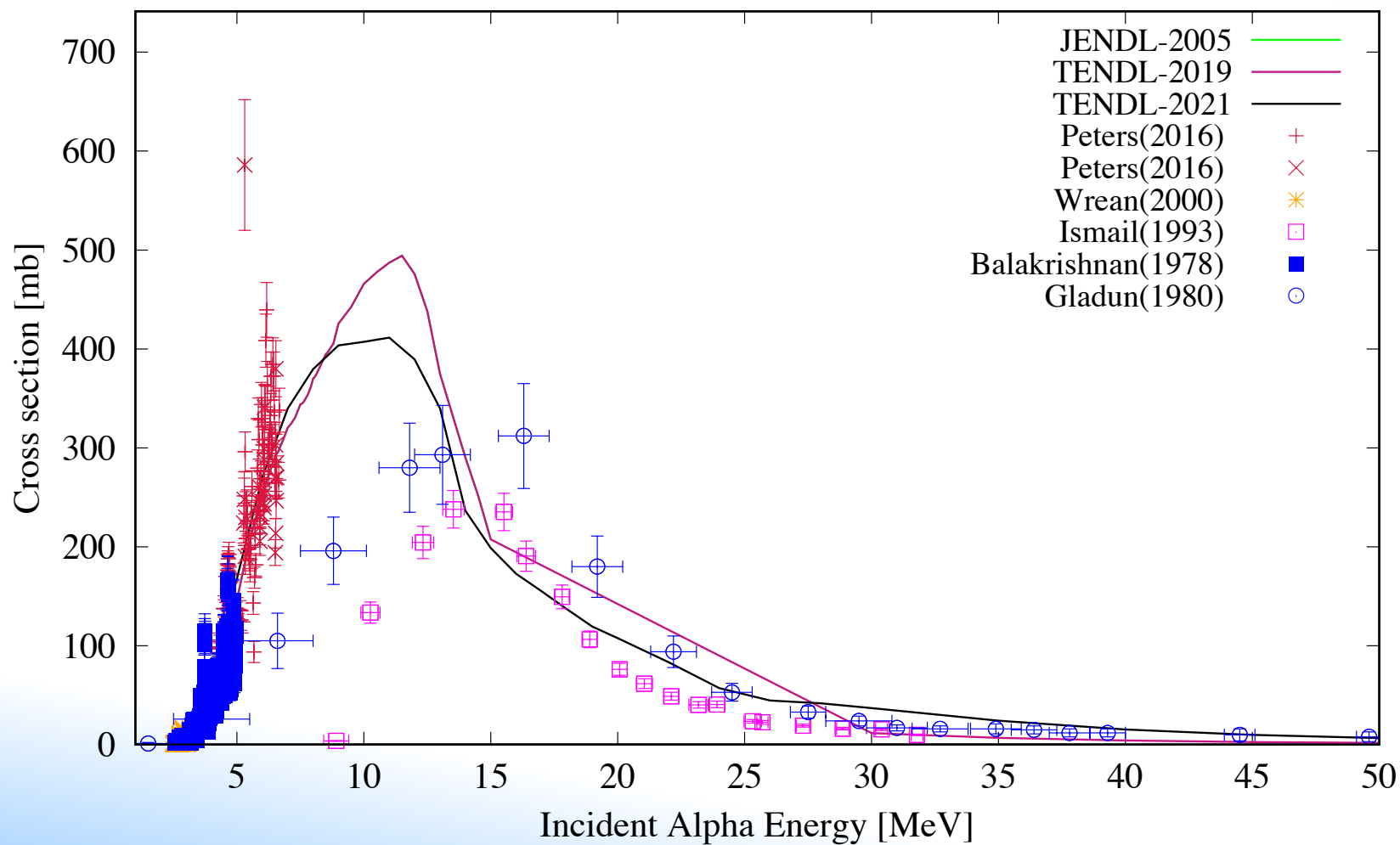
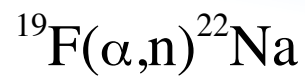


TALYS does not provide resonance structure

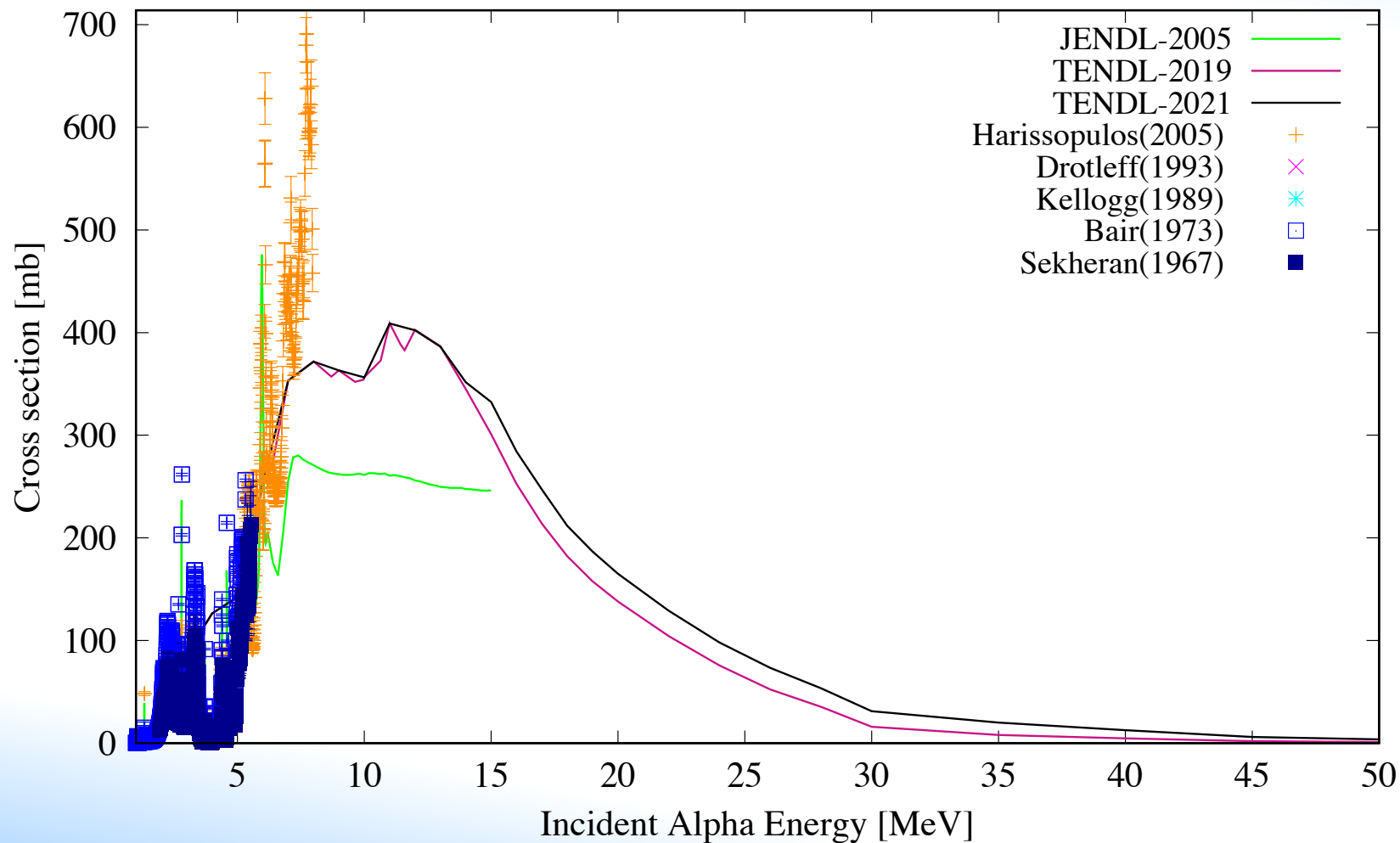


TALYS does not provide resonance structure

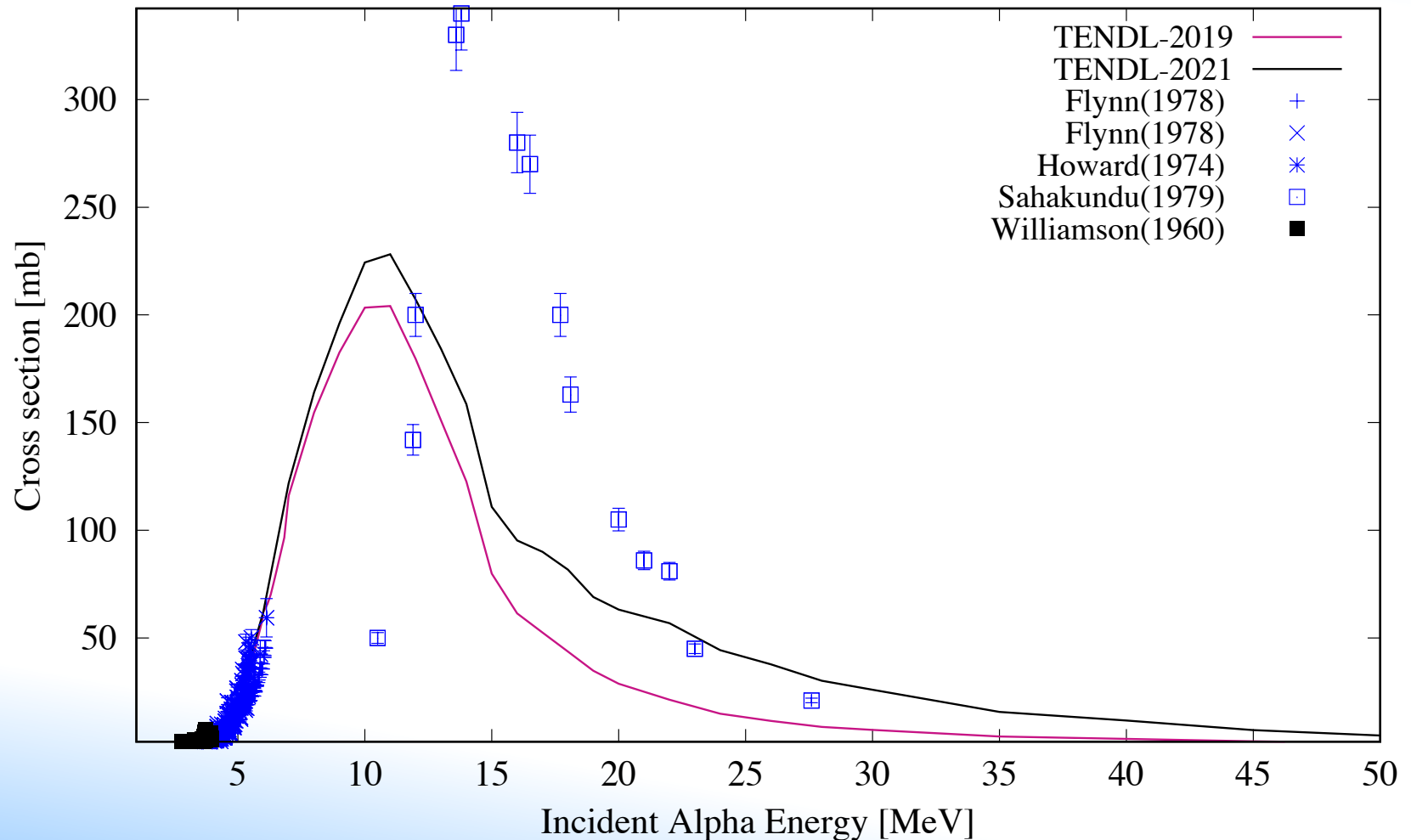
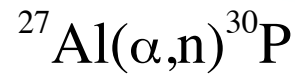




$^{13}\text{C}(\alpha, n)^{16}\text{O}$



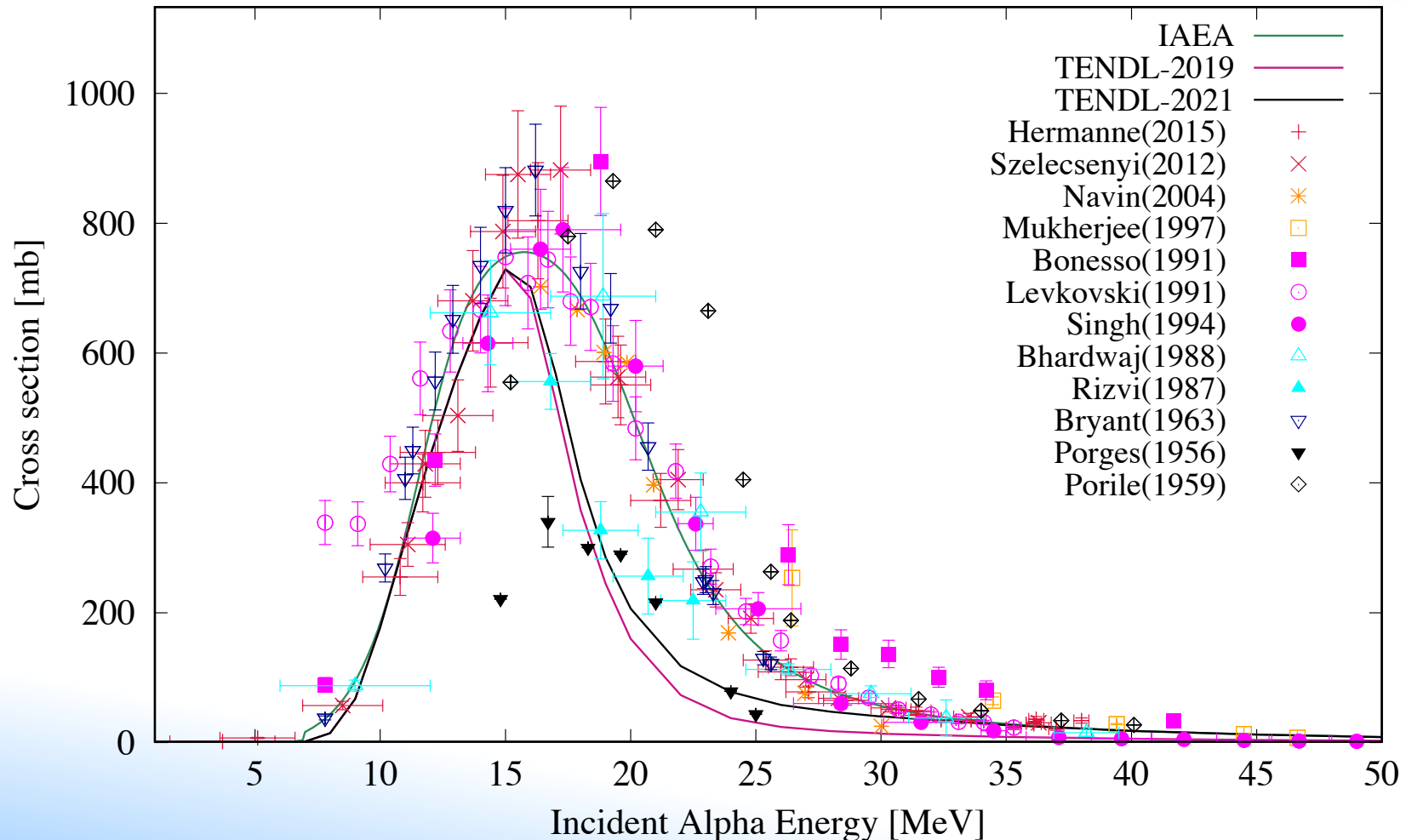
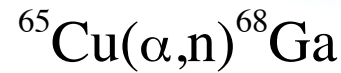
Another suspicious data set?



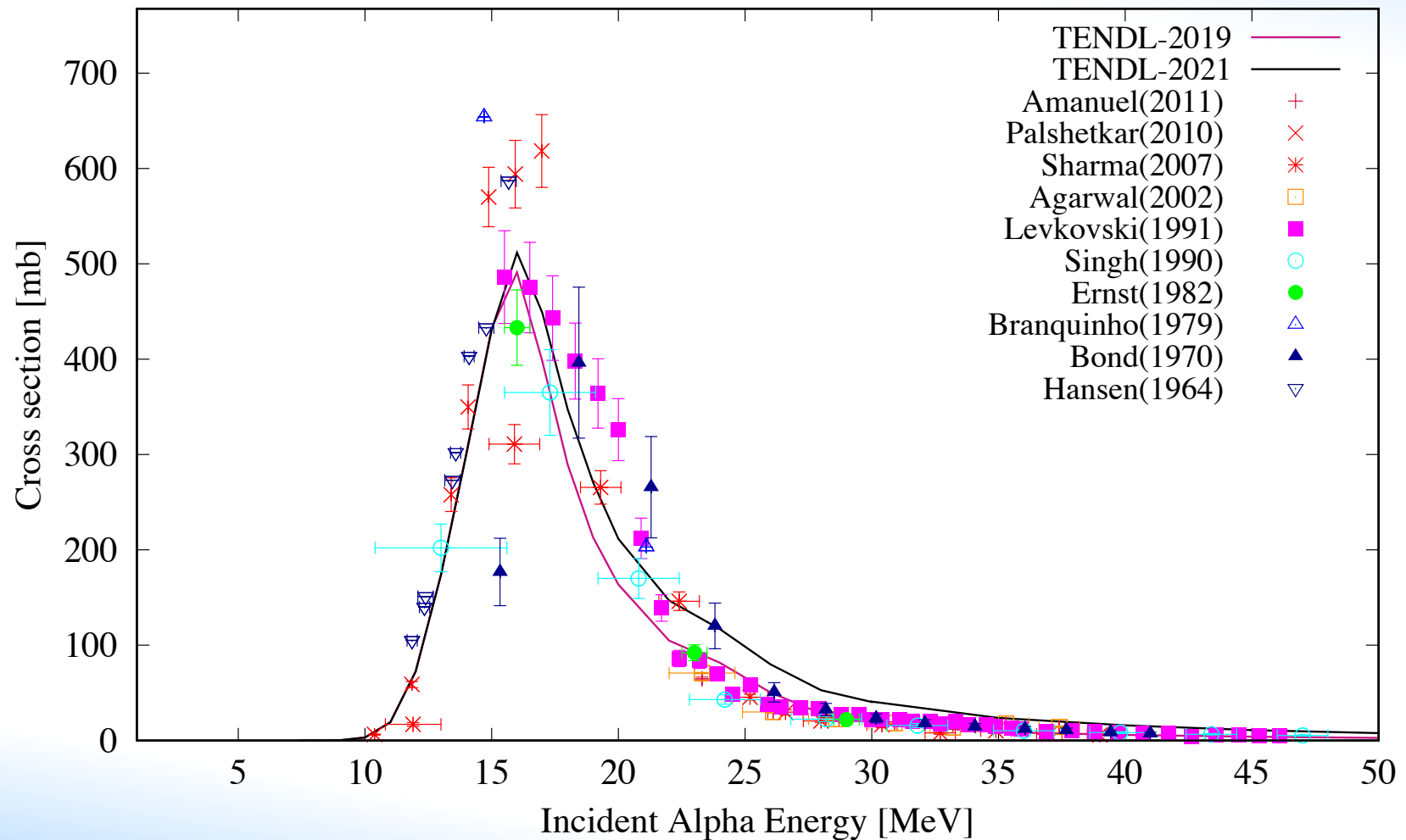
(α , n) route for medical isotopes

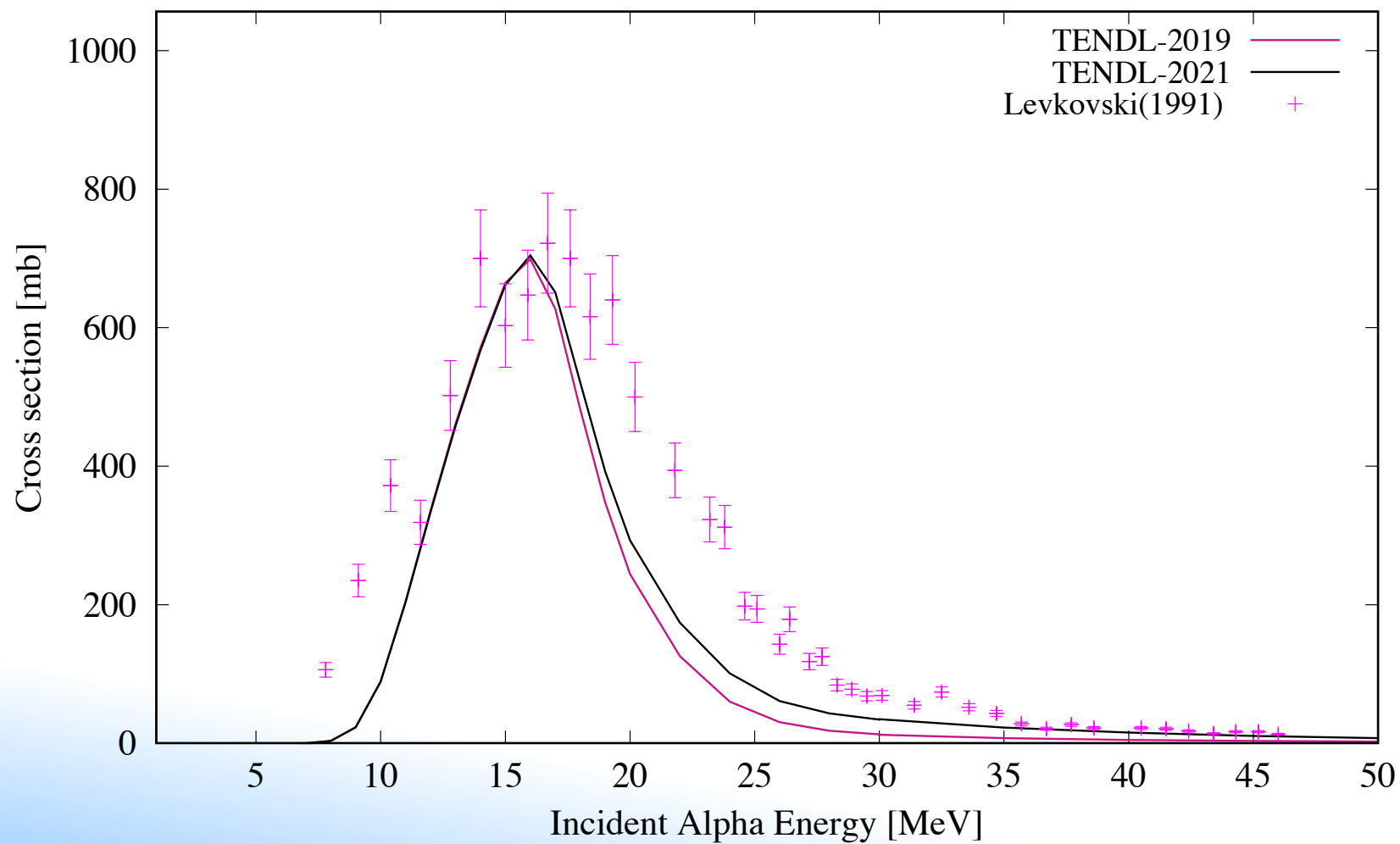


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Sometimes TENDL-2019 better than TENDL-2021?





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!

