



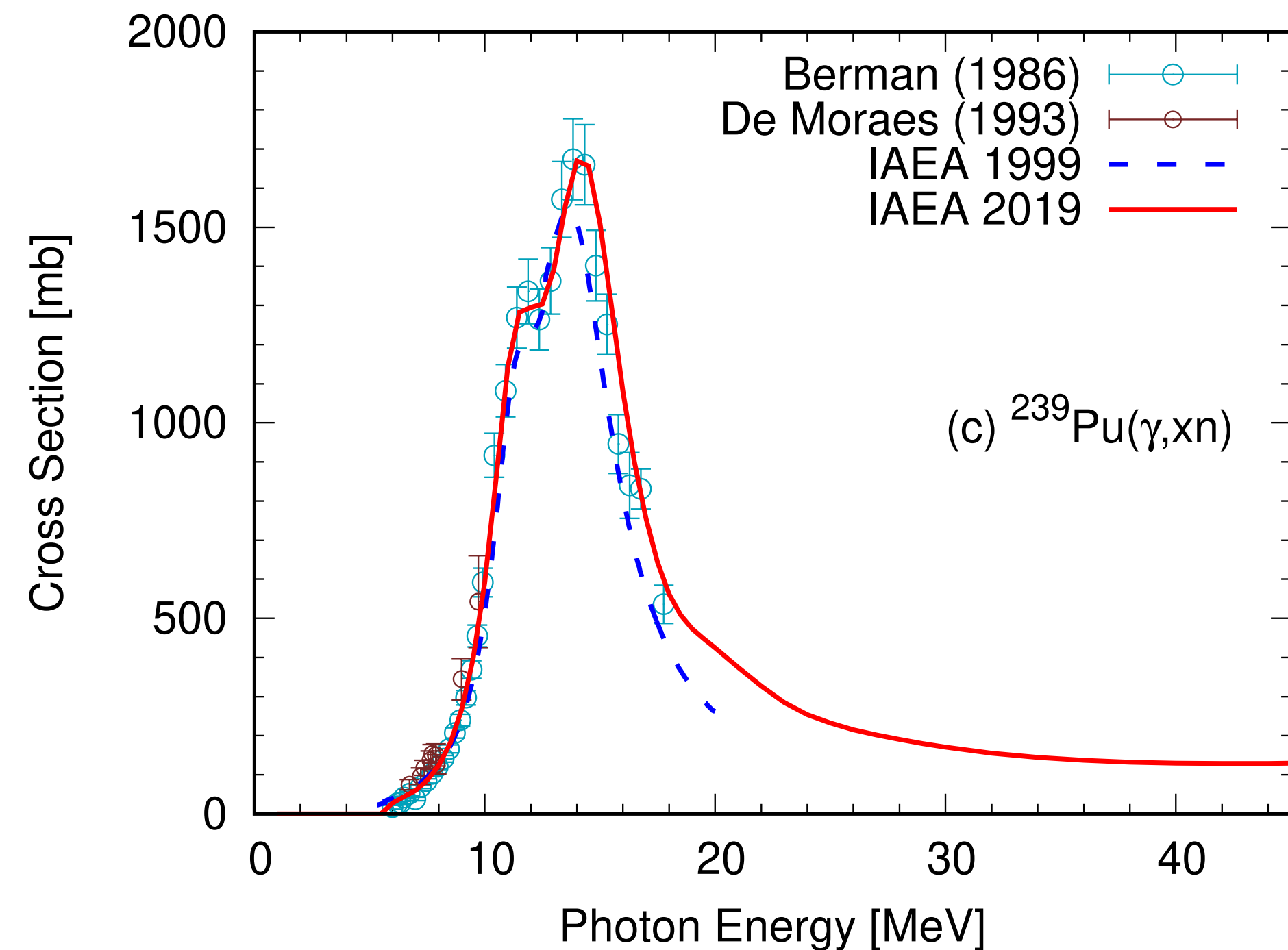
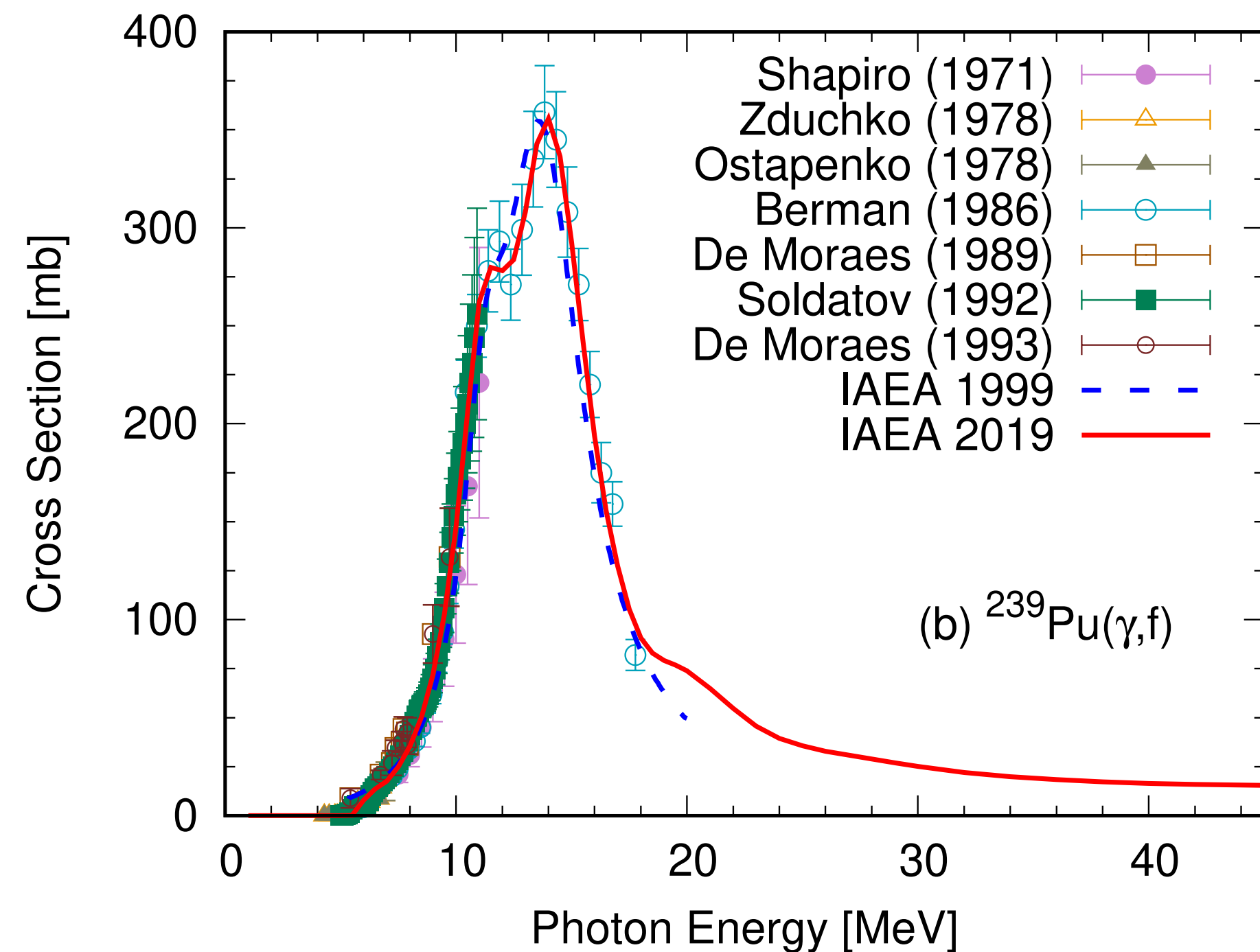
# Preliminary Study on Photo-nuclear Fission Product Yield Evaluation

**T. Kawano, A.E. Lovell**  
**Theoretical Division**

# Photonuclear Fission Data

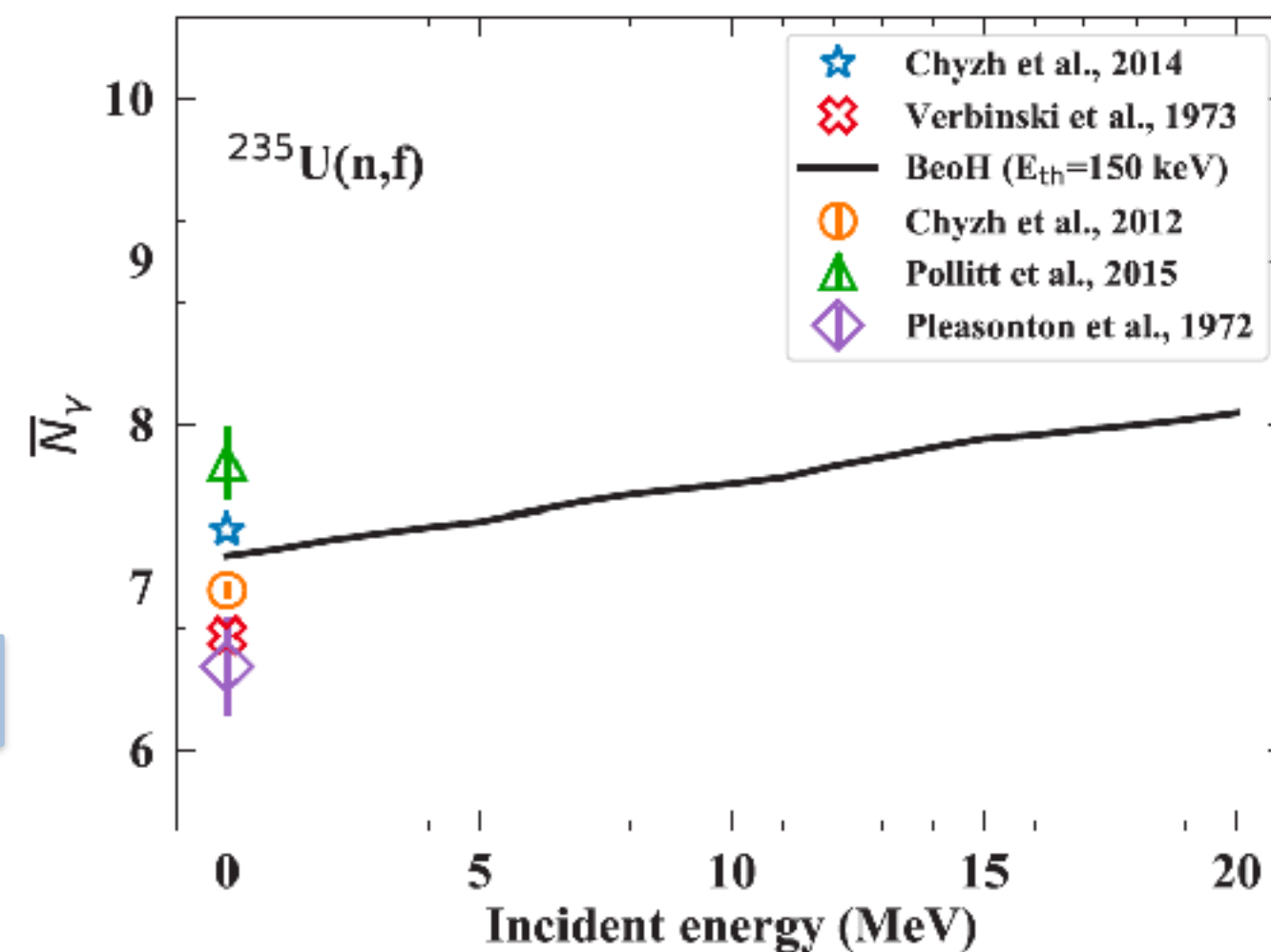
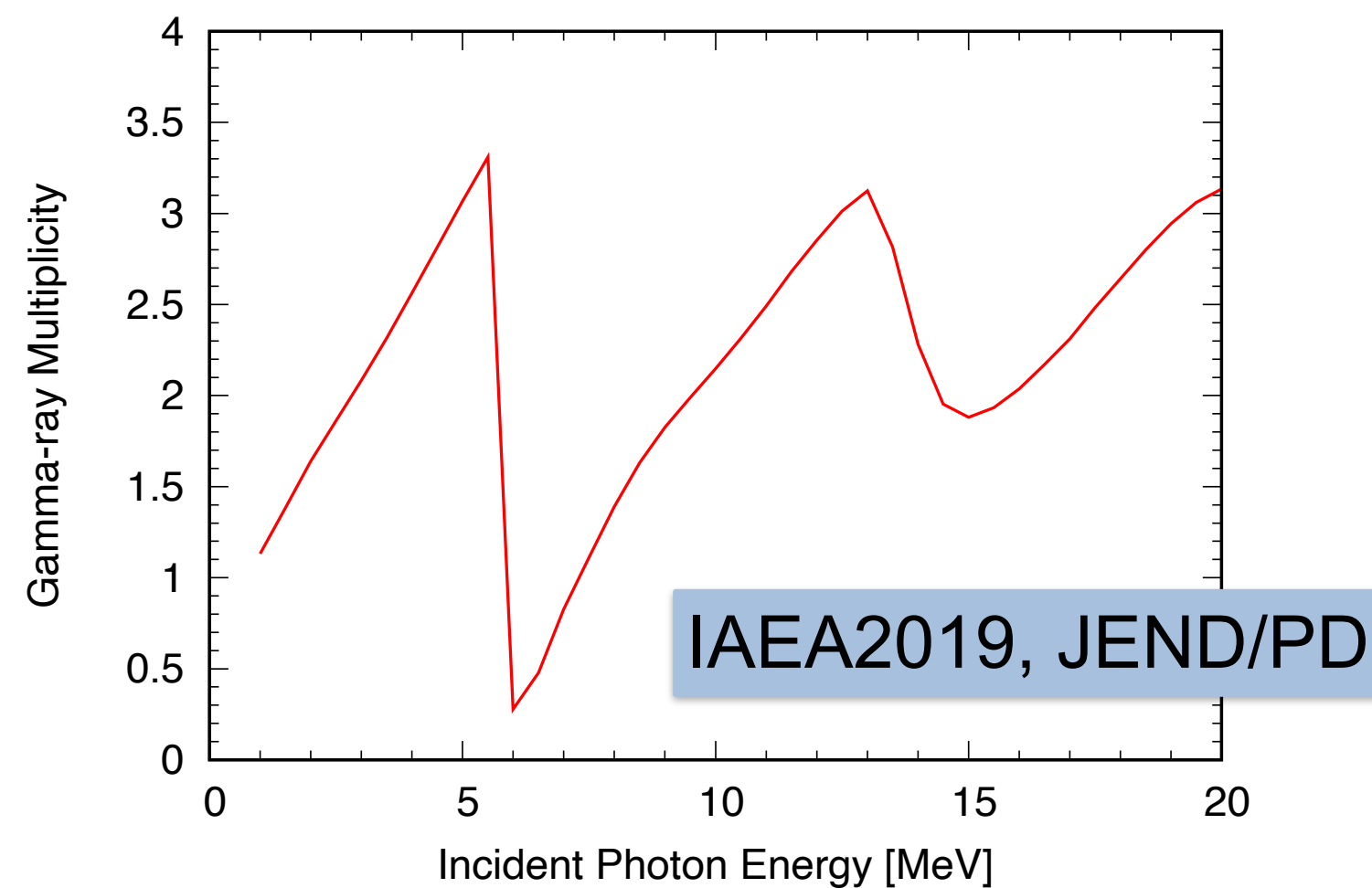
- **IAEA 2019 Photonuclear Data Library**

- IAEA CRP, including both the photon strength function and photonuclear data library
- Nuclear Data Sheets 163, 109 (2020)
- Major actinide data evaluated by N. Iwamoto
  - Fission and neutron production cross section fitted by the CCONE code up to 200 MeV

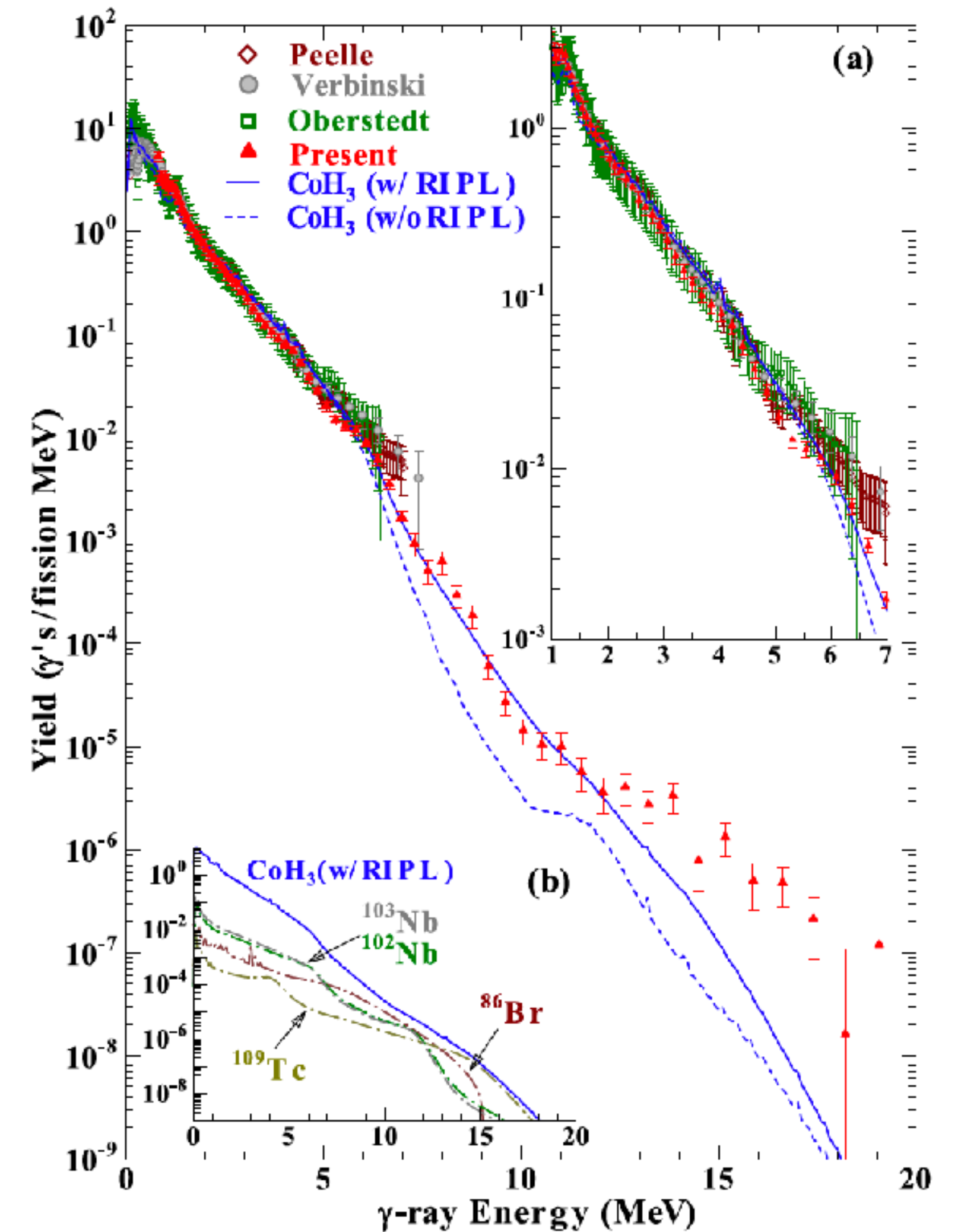


# Photo-Fission Gamma-ray Production

- **Missing section reported by users**
  - Prompt fission neutron spectrum given, but MF6/MT5 for SAP = 0 includes channels other than fission only
    - Fission gamma-ray multiplicities should be high
    - MF12/MT18 and MF15/MT18 are also missing
- **Hauser-Feshbach Fission Fragment Decay (HF<sup>3</sup>D) model**
  - Published in PRC by Lovell et al. is able to produce the fission gamma-rays, at least up to 20 MeV or so.



A.E. Lovell, PRC 103, 014615 (2021)

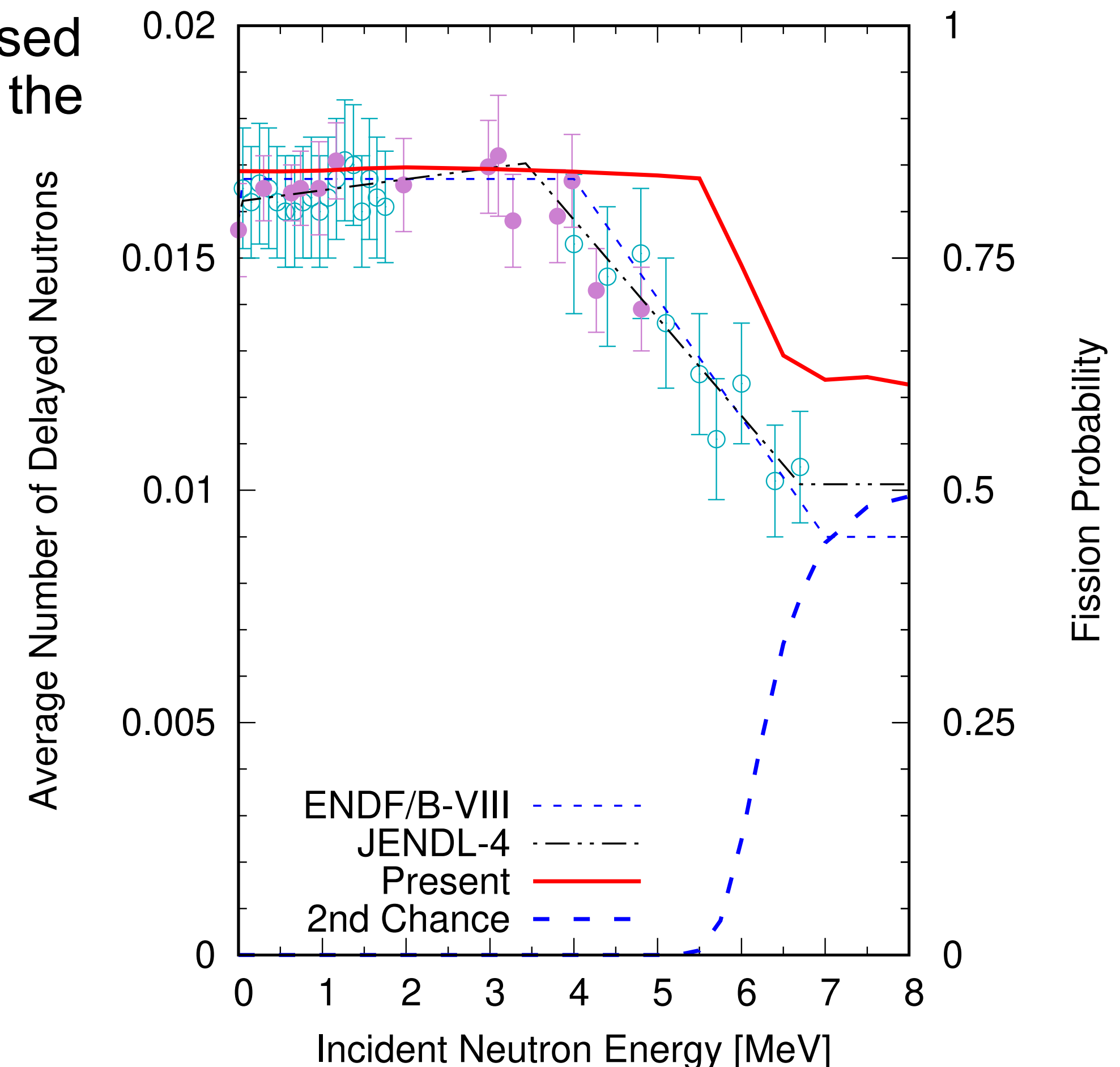


H. Makii, PRC 100, 044610 (2019)



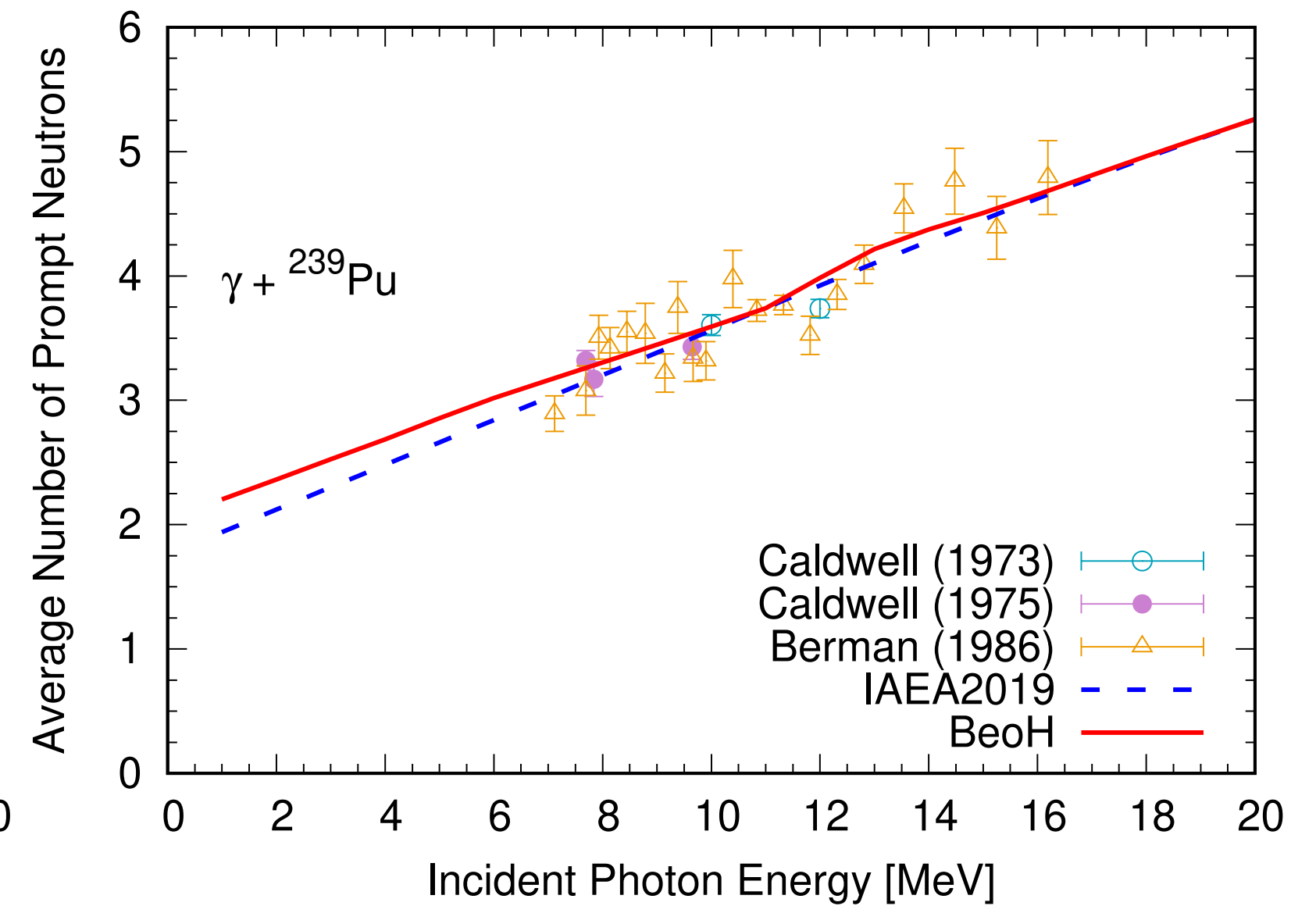
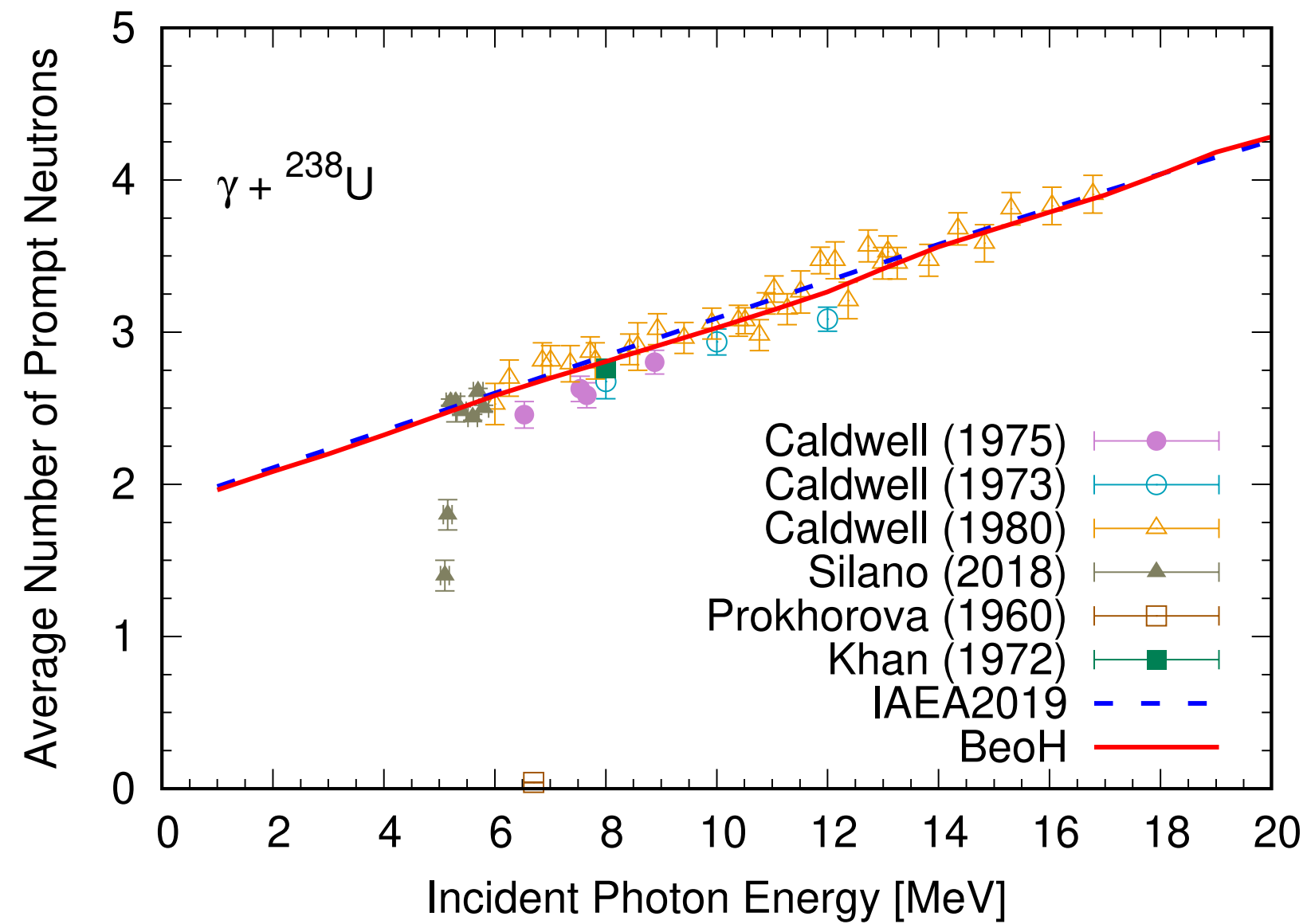
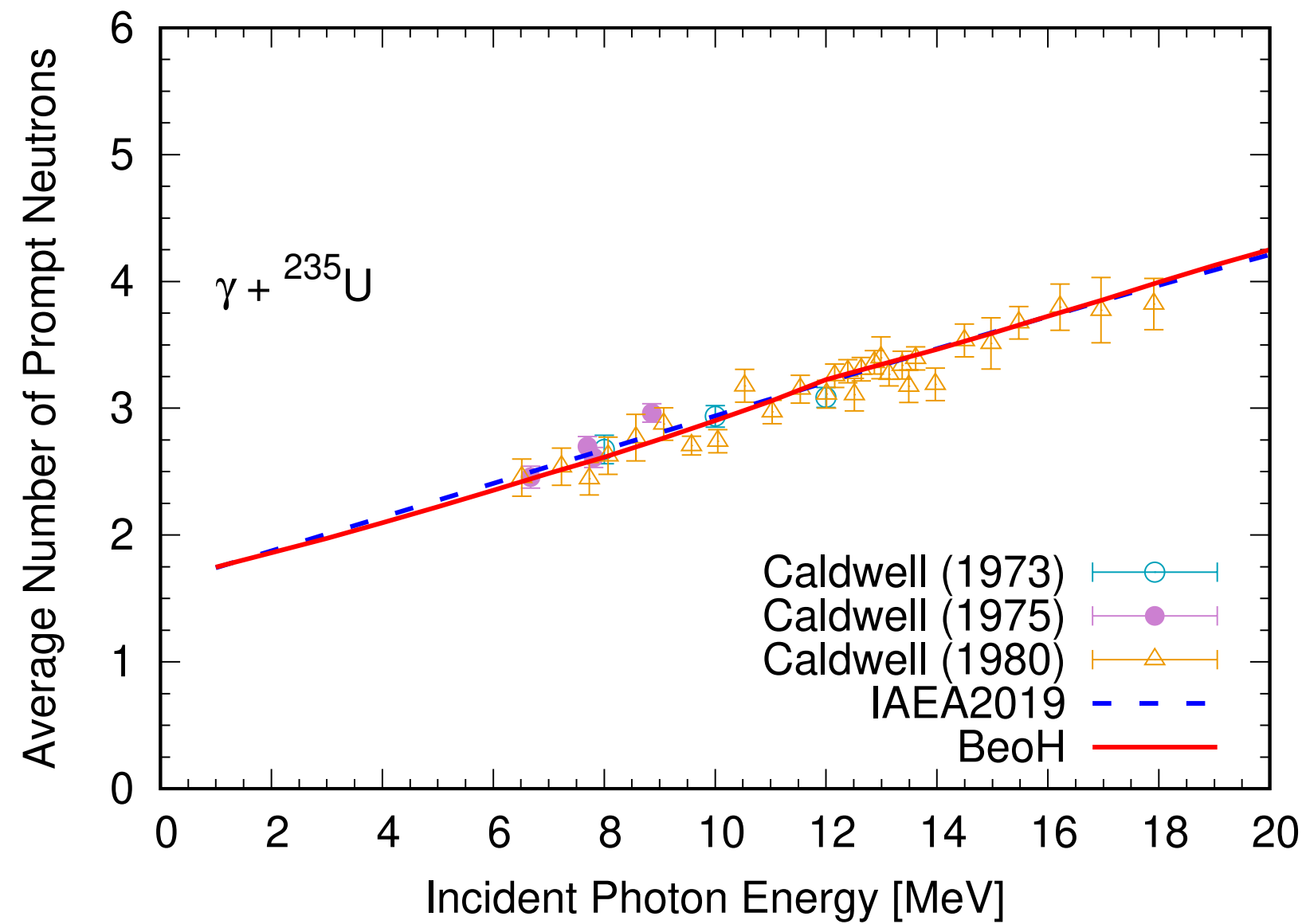
# CoH<sub>3</sub>/BeoH Extended to Photo-induced Multi-Chance Fission

- **Evaluation of gamma-ray production from photo-nuclear fission needs FPYs for gamma-ray induced fission**
  - prompt gamma-ray production and FPY obtained simultaneously
  - Photo-nuclear reactions on <sup>235</sup>U, <sup>238</sup>U, and <sup>239</sup>Pu calculated based on the BeoH model parameters obtained by Shin Okumura for the neutron-induced fission calculations [JNST 59, 96 (2022)]
- **Procedure**
  - Multi-chance fission probabilities estimated from photo-fission cross section with CoH<sub>3</sub>
  - Energy-dependent mass distribution shifted by the neutron separation energy
  - TKE re-adjusted to fit to prompt neutron multiplicities
  - All other parameters remain the same as Okumura's
  - Decay data from ENDF/B-VIII.0 decay data library
  - Calculated results converted into ENDF format (MF12/MF15)

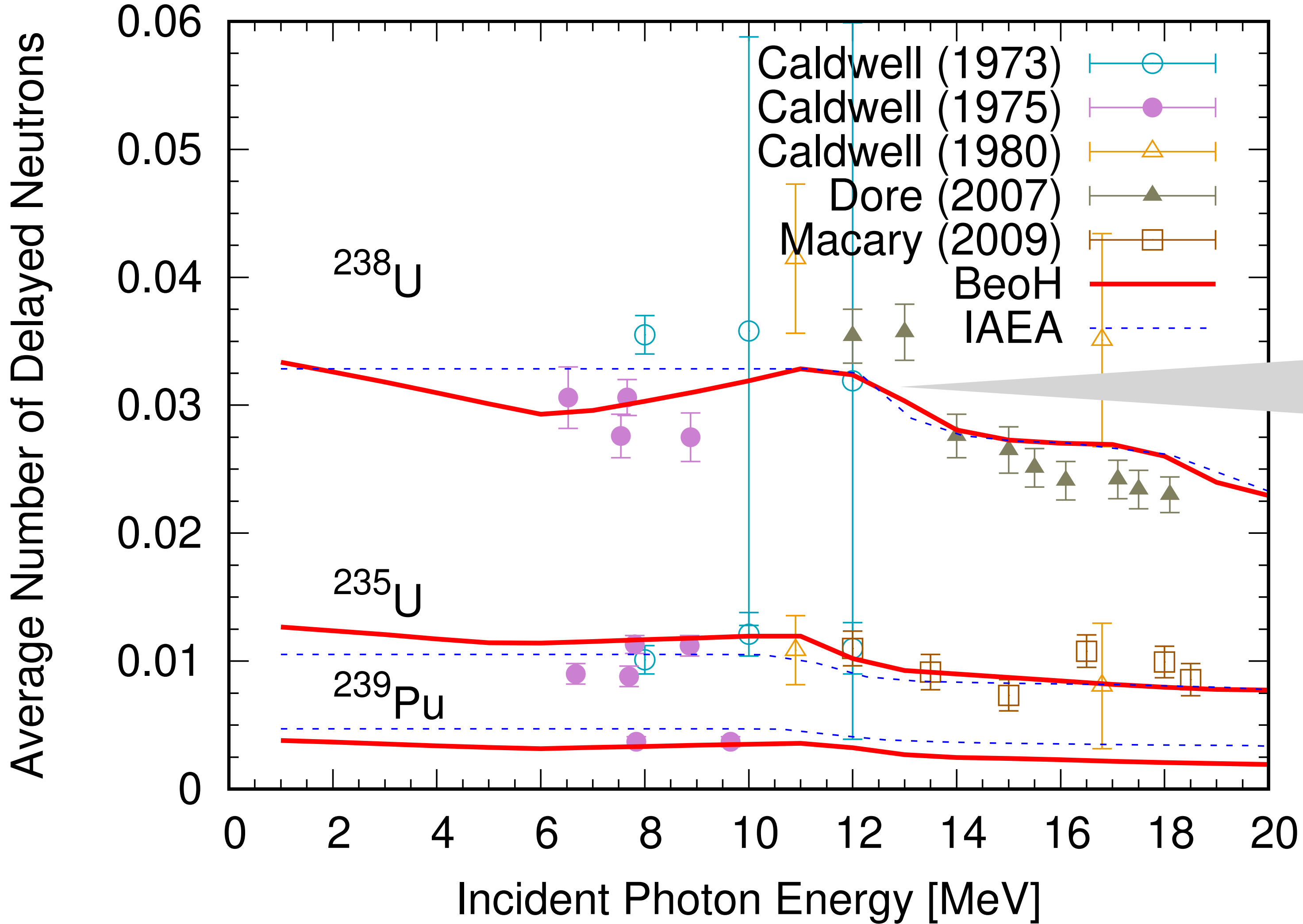


# Average Number of Prompt Fission Neutrons

- These experimental data were fitted by tuning the total kinetic energy, TKE
  - Differences in TKE between neutron and photon incident cases are a few MeV or less

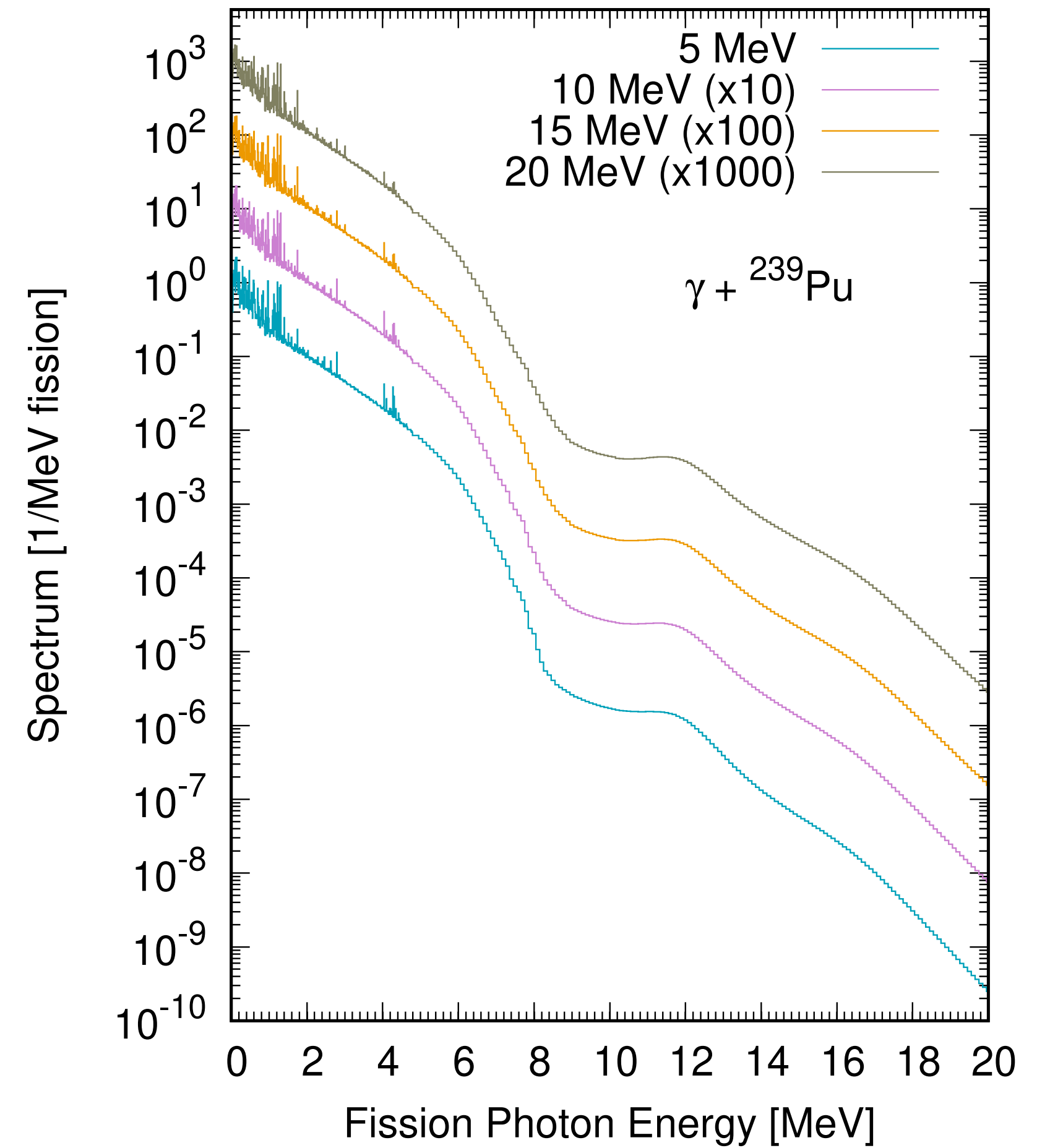
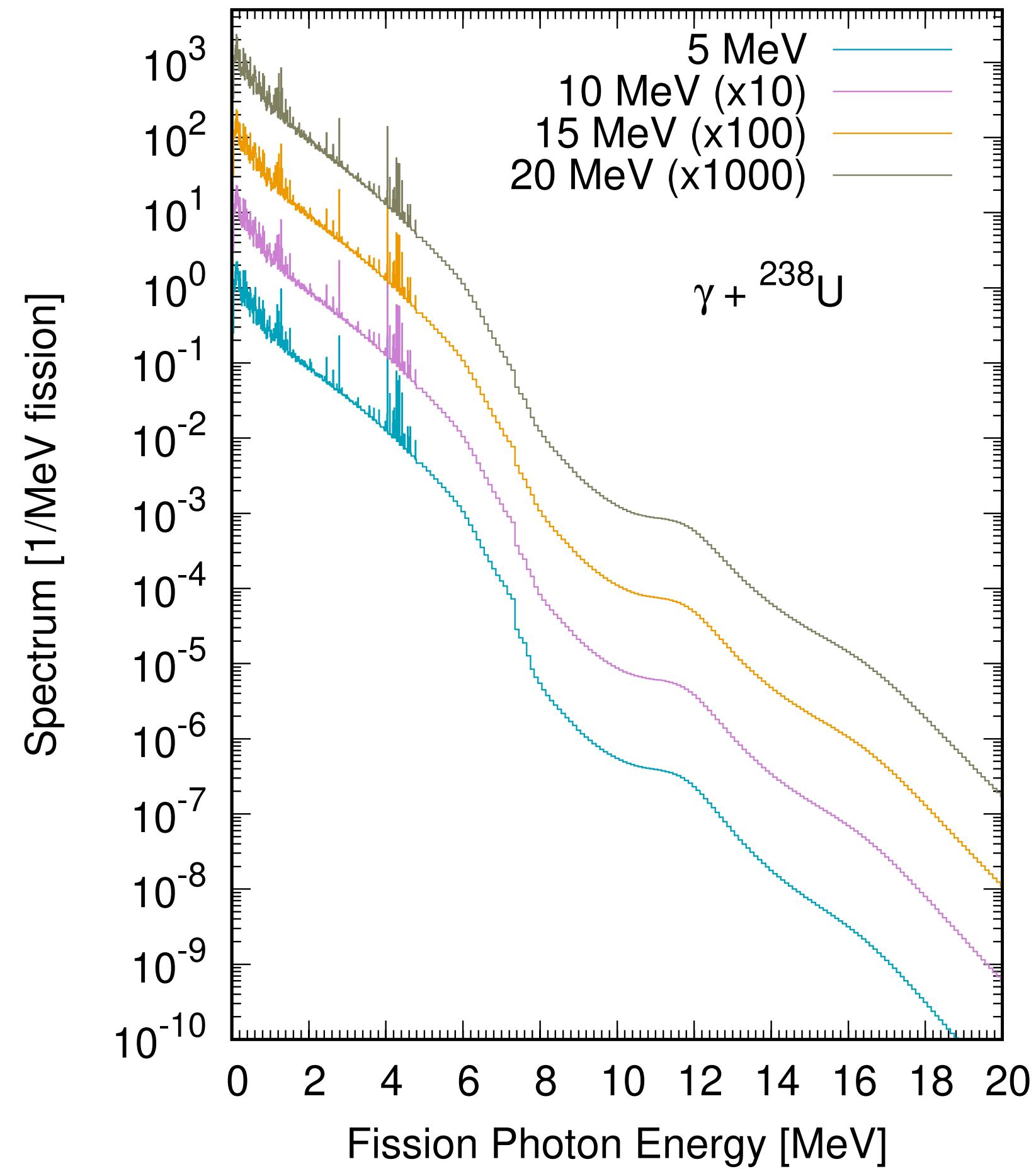
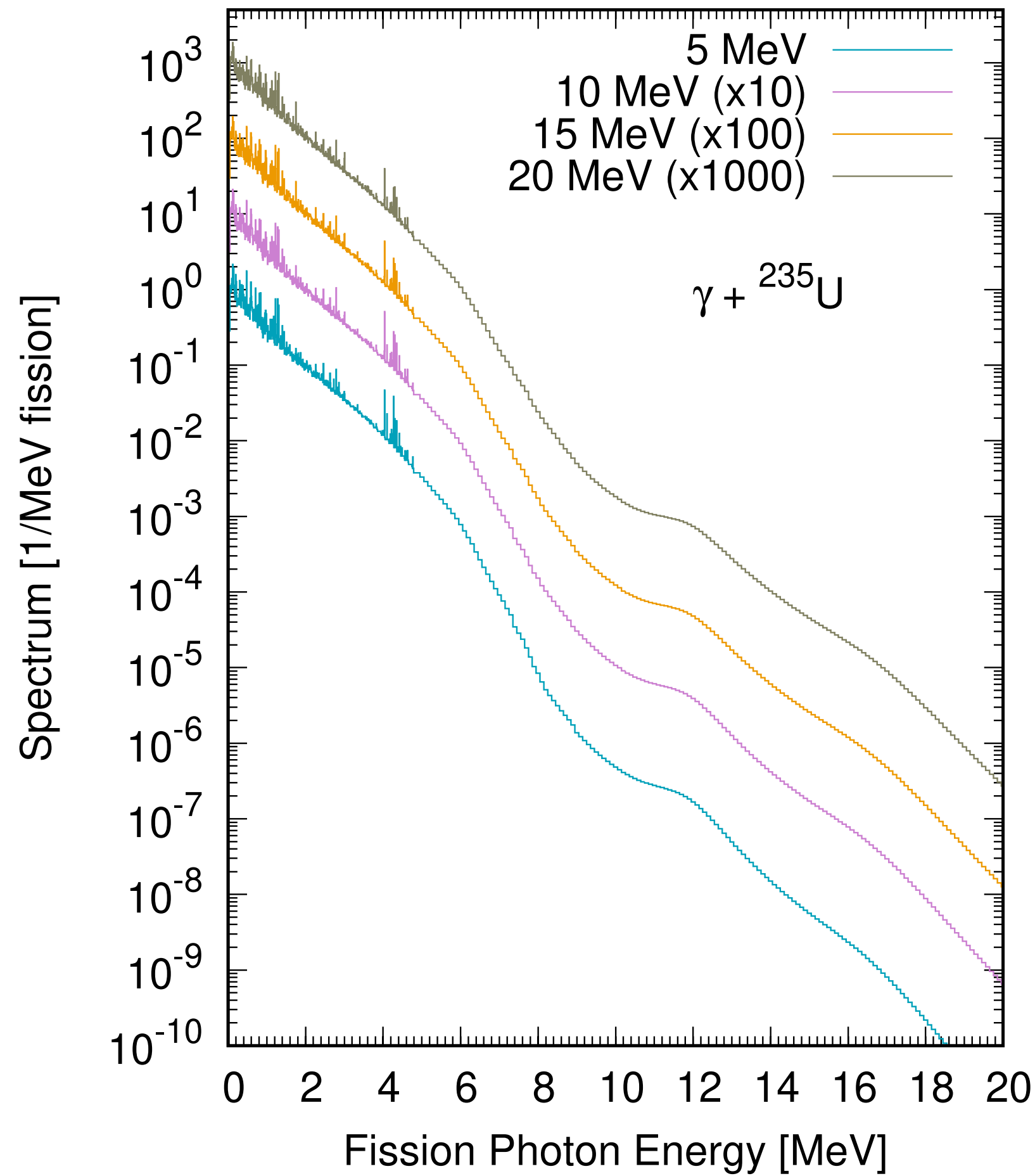


# Average Number of Delayed Neutrons

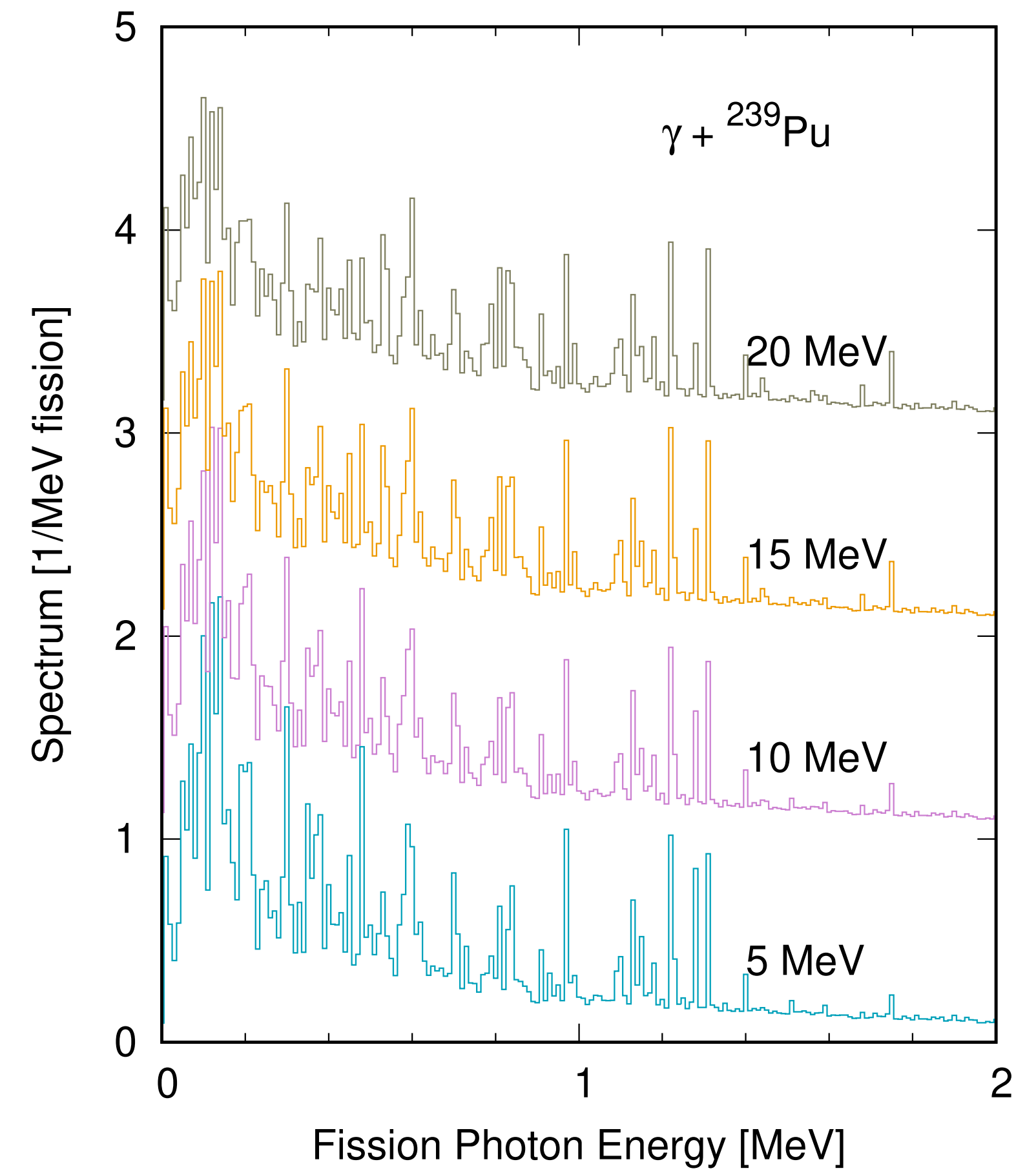
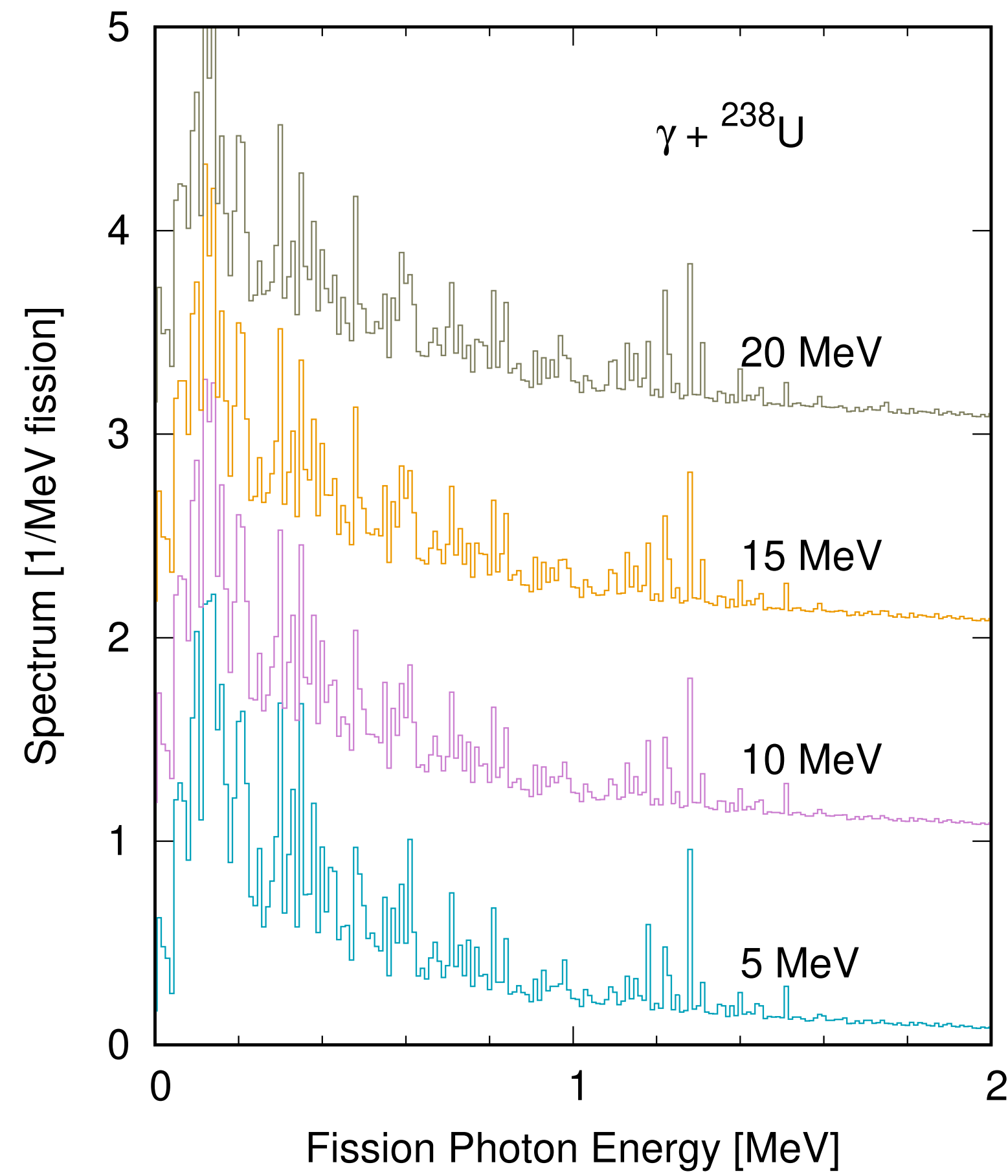
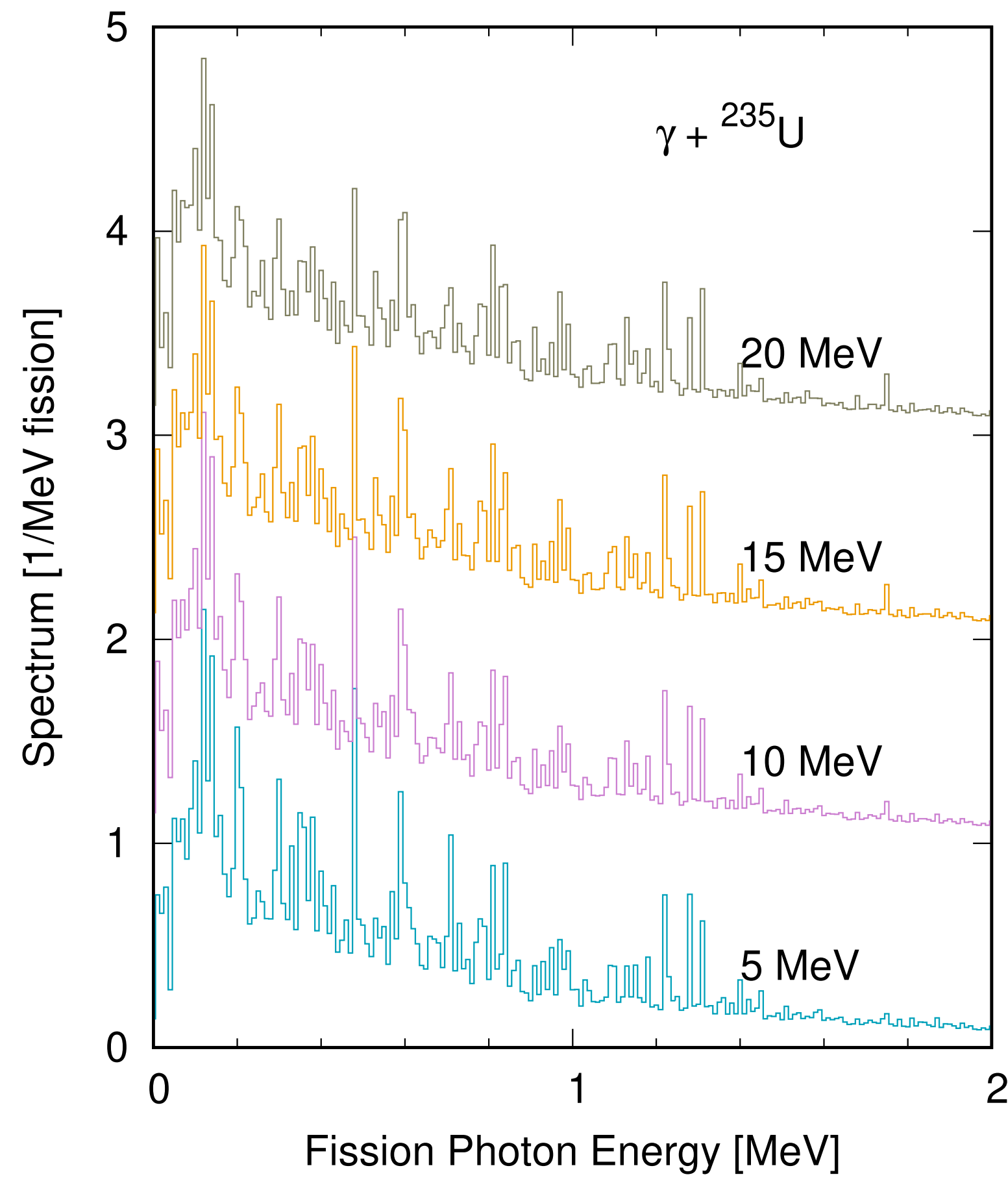


Multi-Chance Fission Effect

# Prompt Fission Gamma-ray Energy Spectra



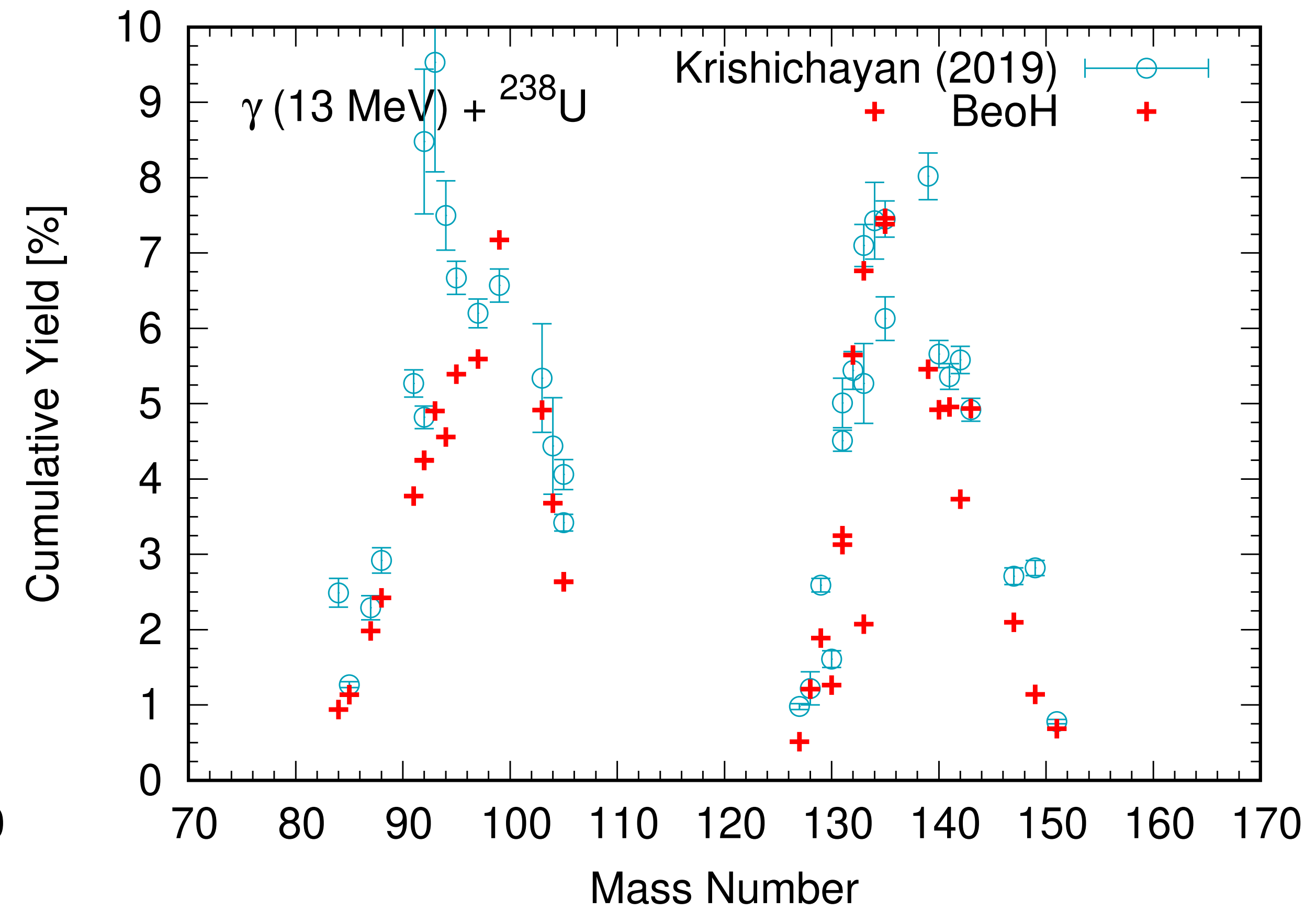
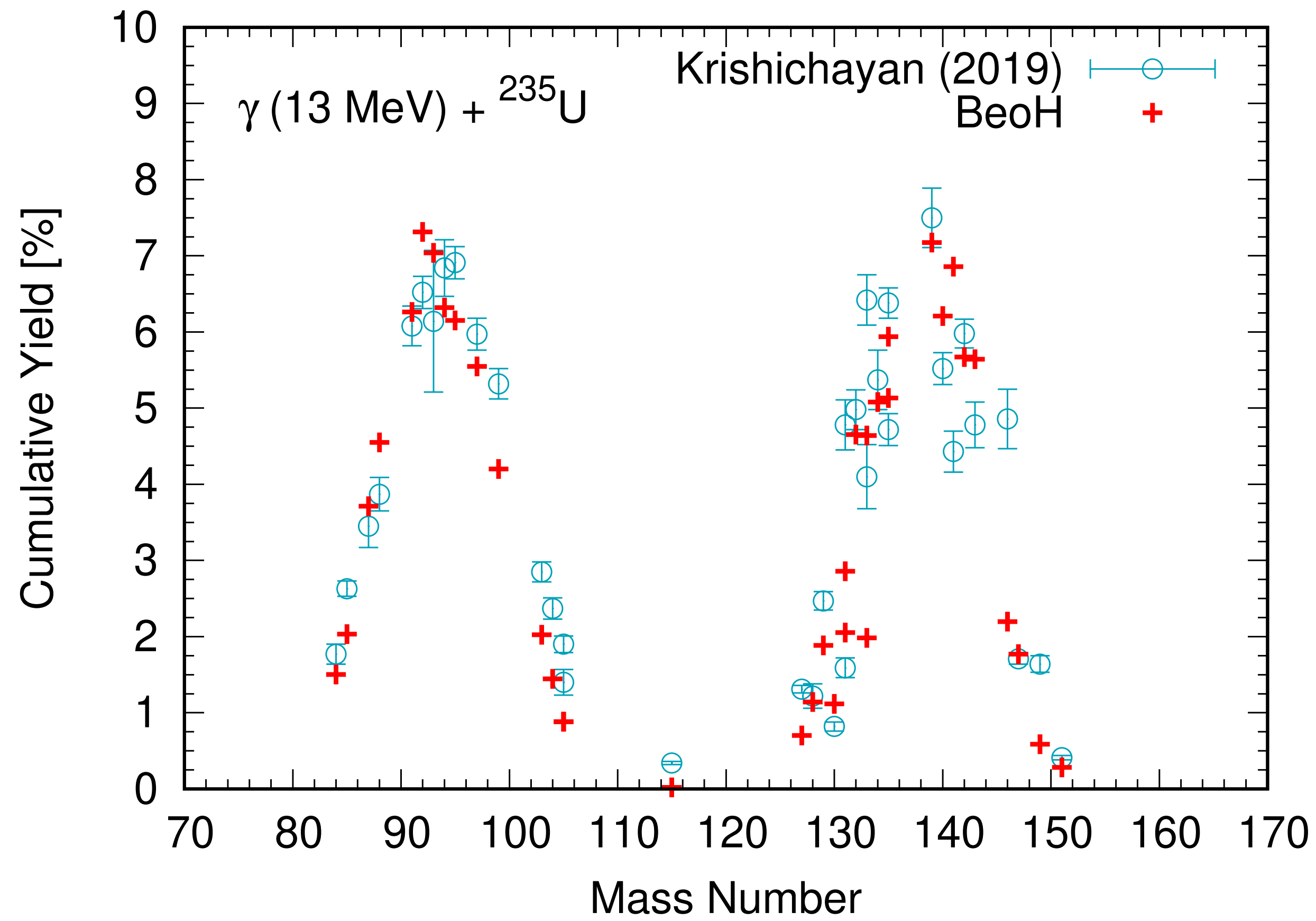
# Prompt Fission Gamma-ray Energy Spectra (magnified)



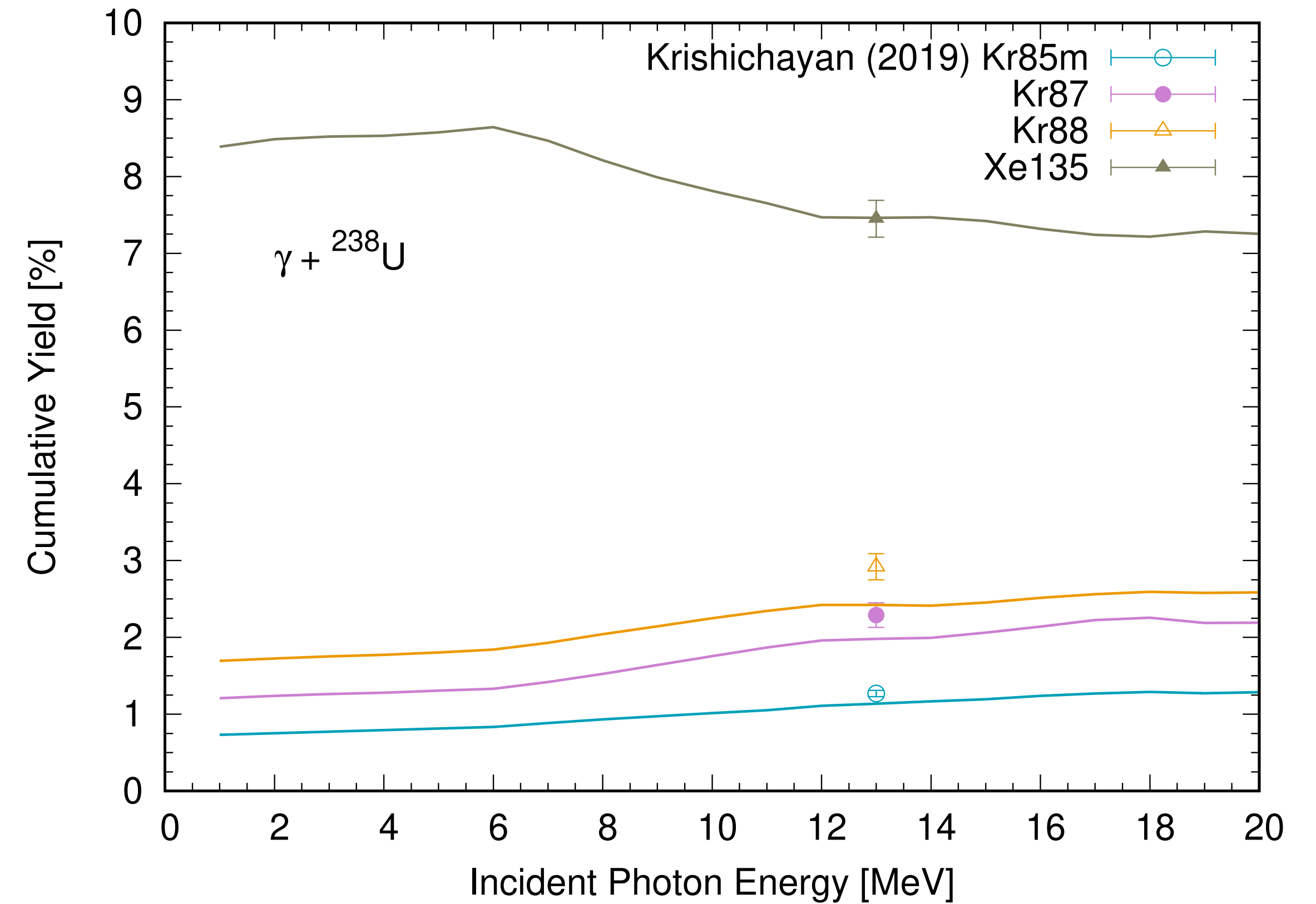
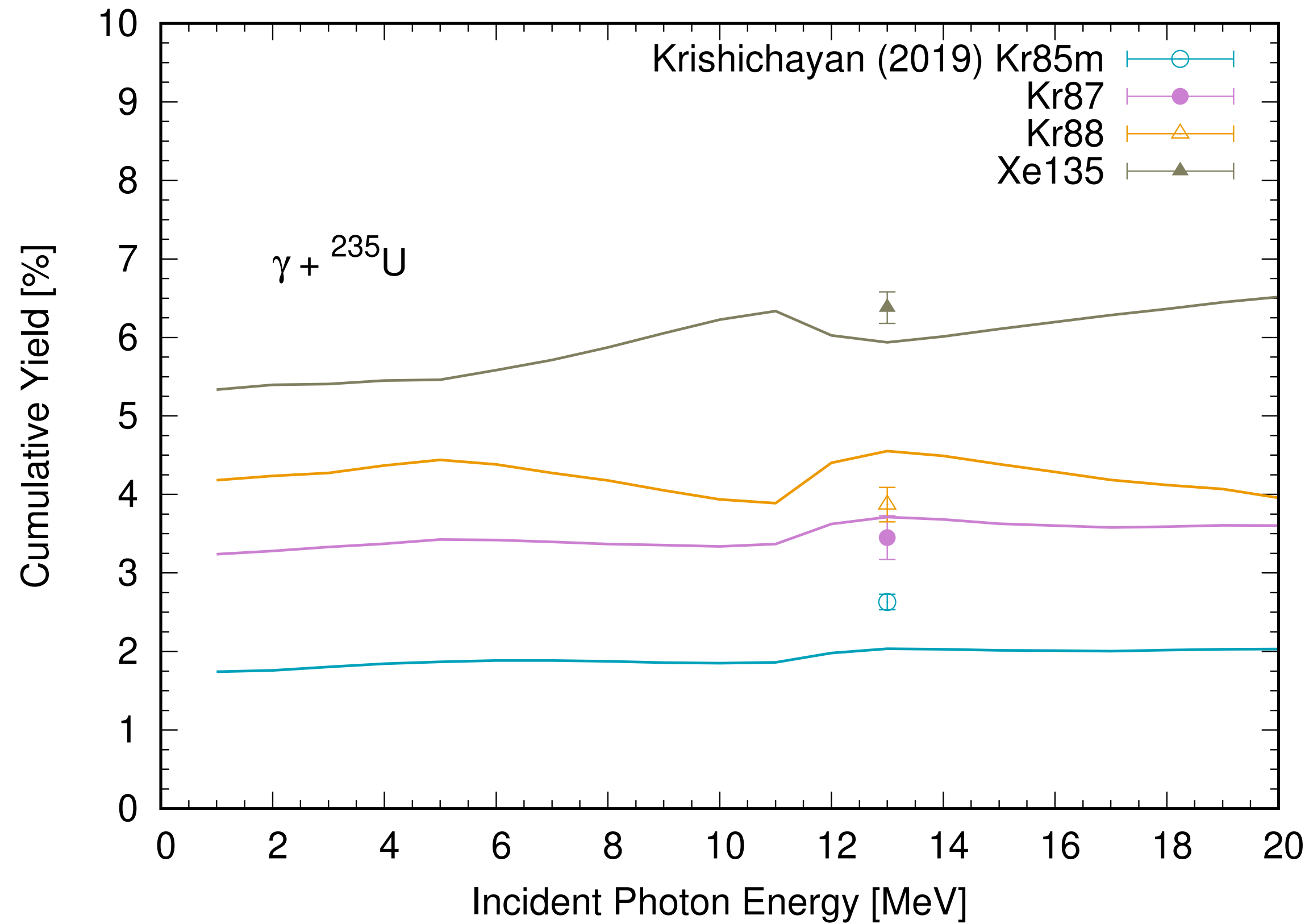


# Photo-Fission Cumulative Fission Product Yields (preliminary)

- Comparison with HlgS data at 13 MeV

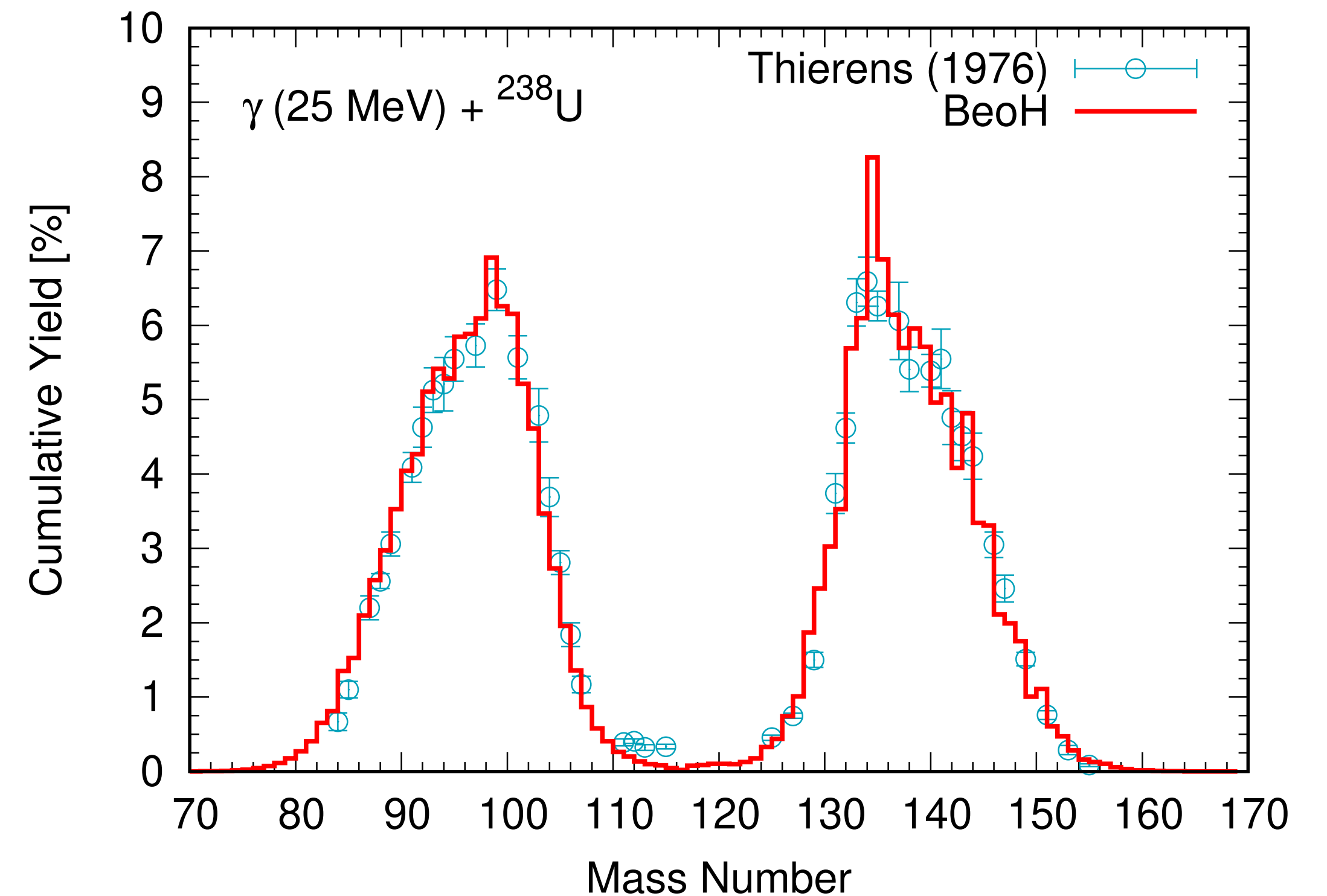
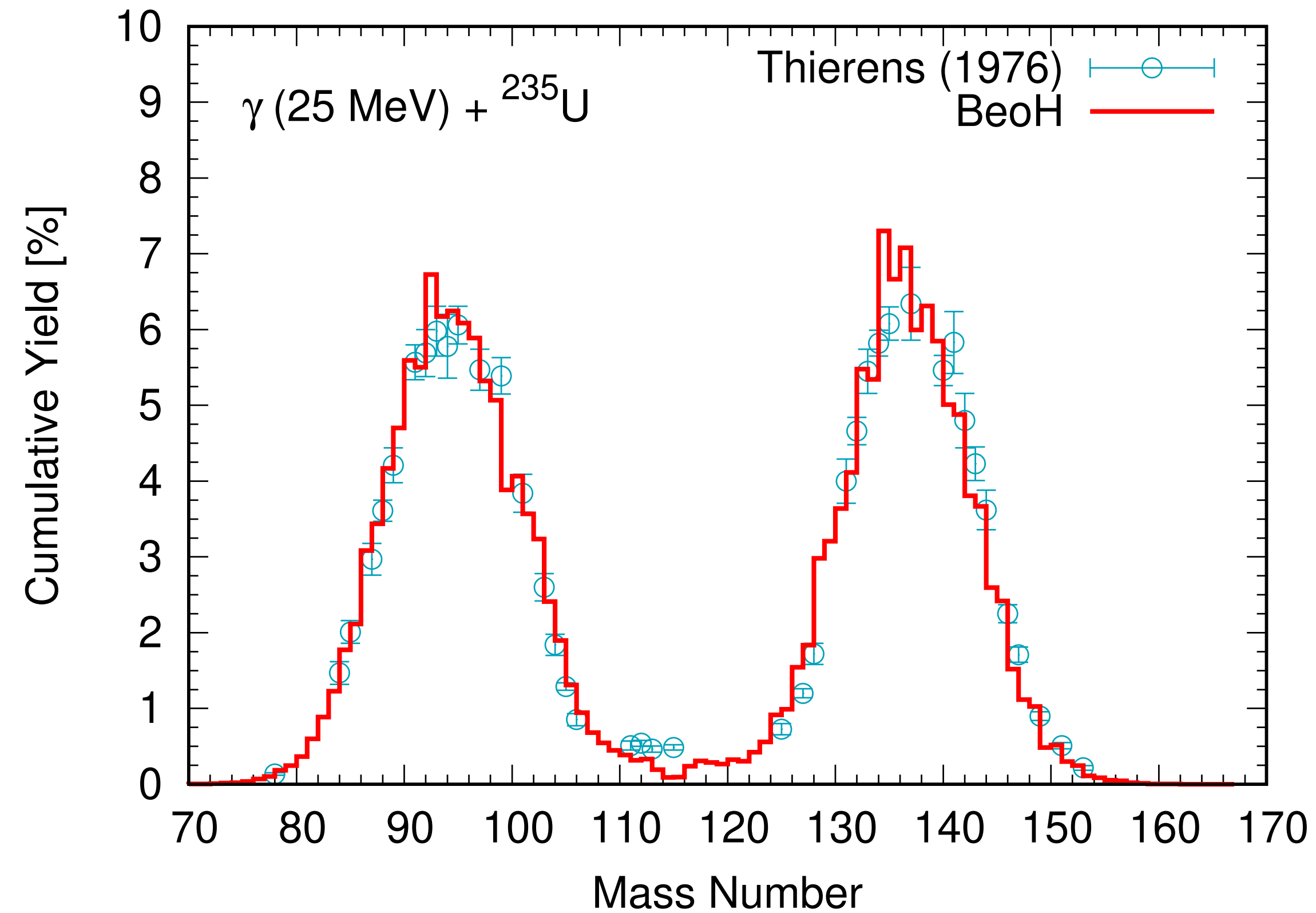


# Energy-Dependent Cumulative FPY (noble gas)



# Cumulative Photo-Fission Mass Yields (Preliminary)

- Comparison with bremsstrahlung data ( $E_{\text{max}} = 25 \text{ MeV}$ )



# Perspective

- **Prompt fission gamma-ray production data**

- Gamma-ray production (energy spectra and multiplicities) for  $^{235}\text{U}$ ,  $^{238}\text{U}$ , and  $^{239}\text{Pu}$  were calculated by the CoH<sub>3</sub>/BeoH codes based on the model parameters for the neutron-induced cases
- Finer energy grid used to keep all the discrete gamma-line structure
- By combining with IAEA2019, ENDF formatted files were prepared

- **Independent and cumulative fission product yields**

- Preliminary data from 1 to 25 MeV produced
- Comparisons with HIGS at 13 MeV and bremsstrahlung data at 25 MeV look reasonable
- Update model parameters by Lovell's new FPY evaluations for neutron-induced fission
- Fine-tuning of model parameters if needed