Theoretical developments for the study of (p,n) reactions at R3B/EXL

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Current goals:

- Theory input for Gamow-Teller resonances and studies of nucleon-nucleus scattering un inverse kinematics.
- Simulation studies for exotic nuclei (Gamow-Teller resonances). Event generator including FSI and others effects.

Charge exchange reactions

- The Gamow-Teller (GT) transition, excited in charge exchange reactions, is the simplest spin-isospin excitation without angular momentum transfer. Its zero angular momentum transfer limit is the allowed β-decay caused by the weak interaction
- A basic understanding for many Astrophysics processes requires reliable knowledge of the GT strength distribution in nuclei far from the stability line within a large excitation energy range

Forward angle (p, n) cross section

The cross section almost factorizes into a nuclear reaction part and a nuclear structure part

$$\frac{d\sigma}{d\Omega^F_{CM}}(q \approx 0) = \frac{\mu_i \mu_f}{\pi^2} \frac{p_f}{p_i} N_\tau |J_\tau|^2 B(F, i \to f)$$

Forward angle (p, n) cross section

- $B(F, i \to f)$ and $B(GT, i \to f)$ are the squares of the Fermi and GT transitions matriz elements
- $J_\alpha \equiv V^C_\alpha(q = 0)$ $(\alpha = \tau, \sigma\tau)$ is the volume integral of the central part of the effective interaction
- N_α is the distorsion factor. It is equal to one in the Plane Wave approximation.

The effective nucleon-nucleus interaction is obtained by folding the nuclear density with parameterizations of (effective) NN interactions

Spin-isospin descomposition of the effective nucleon interaction

$$V_{12}^C(r) = V_0^C(r) + V_\sigma^C(r)\boldsymbol{\sigma}_1\cdot\boldsymbol{\sigma}_2 + V_\tau^C(r)\boldsymbol{\tau}_1\cdot\boldsymbol{\tau}_2 + V_{\sigma\tau}^C(r)\boldsymbol{\sigma}_1\cdot\boldsymbol{\sigma}_2\boldsymbol{\tau}_1\cdot\boldsymbol{\tau}_2 \quad (4)$$

- $\mathbf{r}$ is the relative coordinate of the two interacting nucleons
- At small-momentum transfer, non central parts of the effective potential (spin-orbit and tensor terms) can be neglected
- In a charge exchange (p,n) reaction, only V_τ^C (Fermi) and $V_{\sigma\tau}^C$ (Gamow-Teller) contribute

- The effective interactions employed in the analysis of (p,n) reactions (relativistic or nonrelativistic) are usually 20 years (or more) old
- A number of parameterizations exist, that may yield rather different results. They can be tested against elastic data at the energies and for the nuclei of interest
- At present, we have implemented a partial wave approach, solving exactly Dirac or Schrödinger equation for the scattering states (distorted waves, hence DW approach) in order to produce:
  - Phase-shifts for elastic scattering
  - Distortion factors for (p,n) reactions

Kinematics of the TEST experiment

KINEMATICAL EXAMPLE FOR $^{136}Xe(p,n)^{136}Cs$

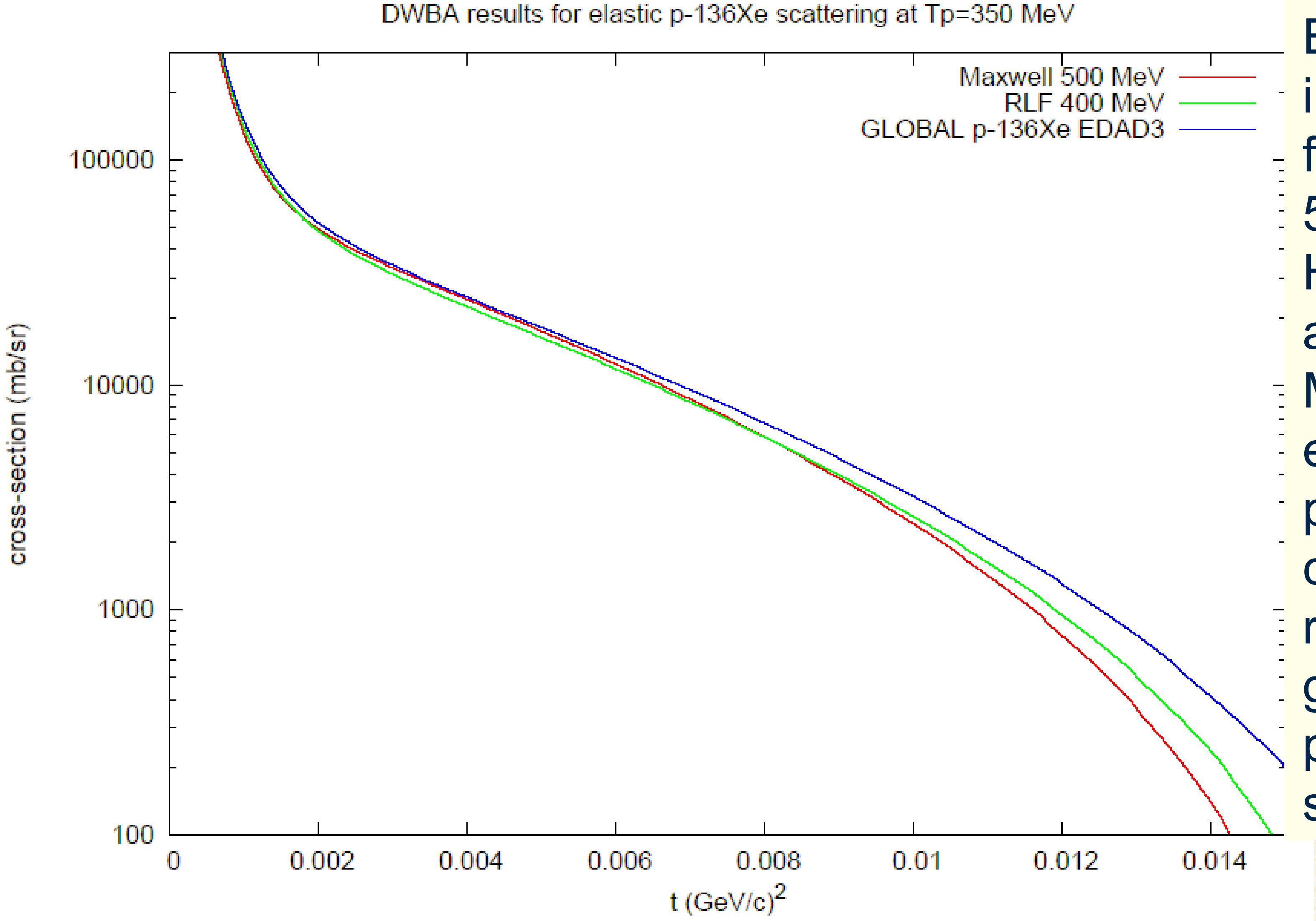
Input GSI:

- T_A = 350 MeV/u
- θ_B = 0.0001° to 0.2°
- θ_n = 70.0° to 80.0°

In the next table, energies in MeV and angles in degrees:

	GSI	LAB	CM
E_x		0.0 to 35.0	
T_n	0.0 to 100.0	315.0 to 355.0	310.0 to 350.0
T_p	0.0	352.6	346.5
θ_n	70.0 to 80.0	0.0 to 30.0	0.0 to 30.0
θ_B	0.0001 to 0.2	64.0 to 84.0	

Elastic cross-section prediction to test the effective interaction



Effective interactions taken from Maxwell (at 500 MeV) or Horowitz+Love and Franey (at 400 MeV) are employed to produce elastic cross-section. As a reference, a globally fit optical potential is also shown.

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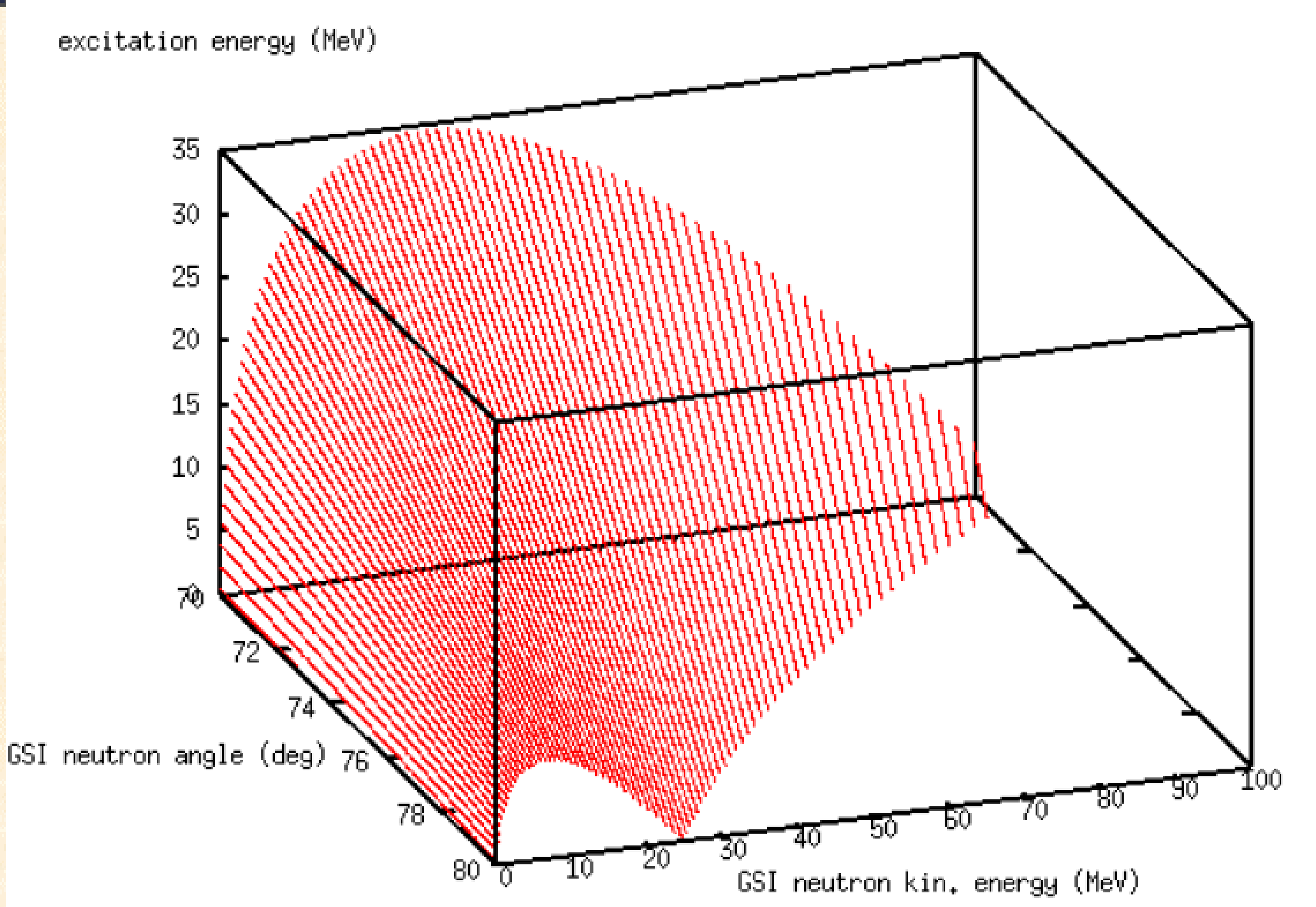
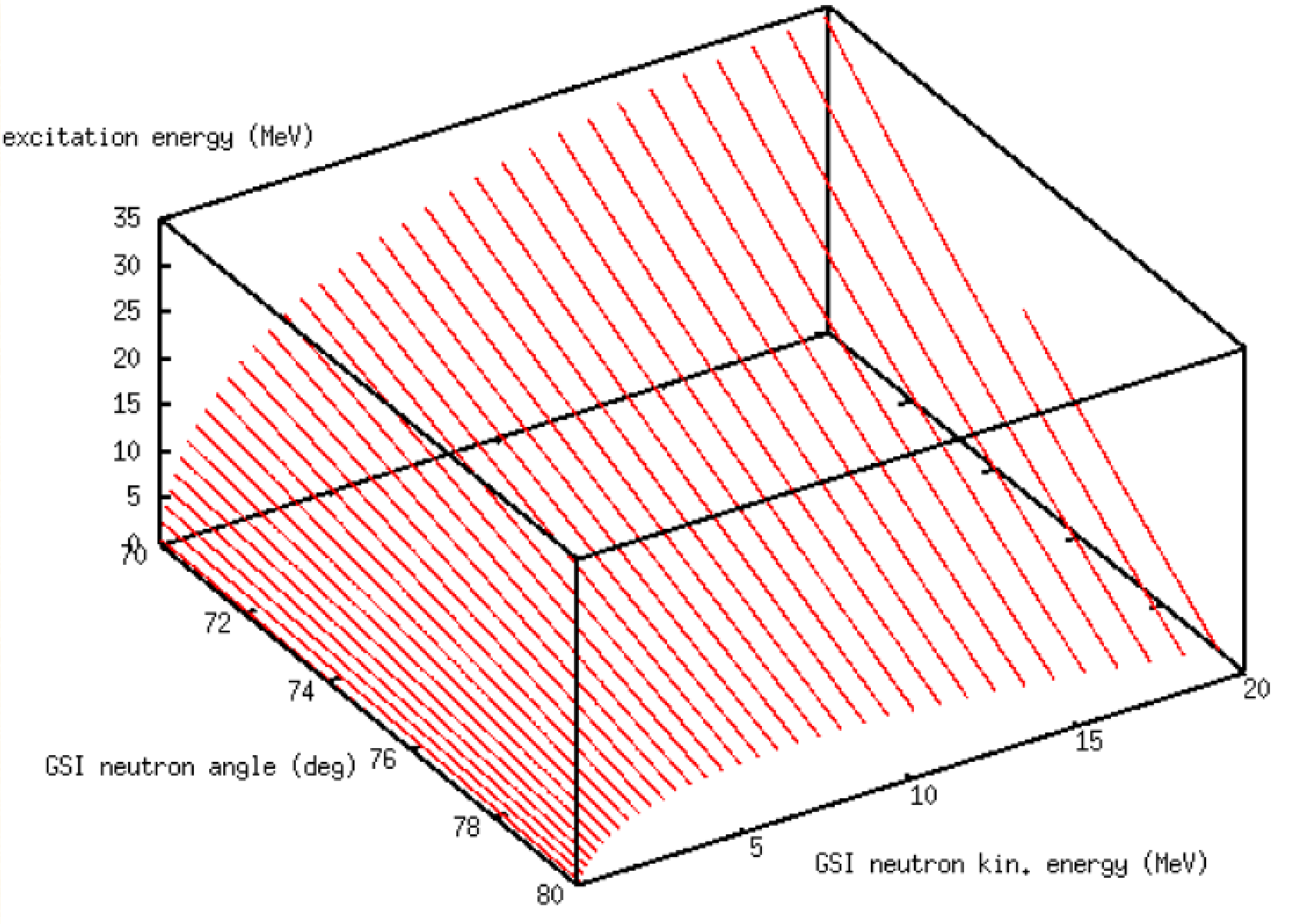
Survey of the kinematics spanned by the TEST experiment



Survey of the kinematics spanned by the TEST experiment



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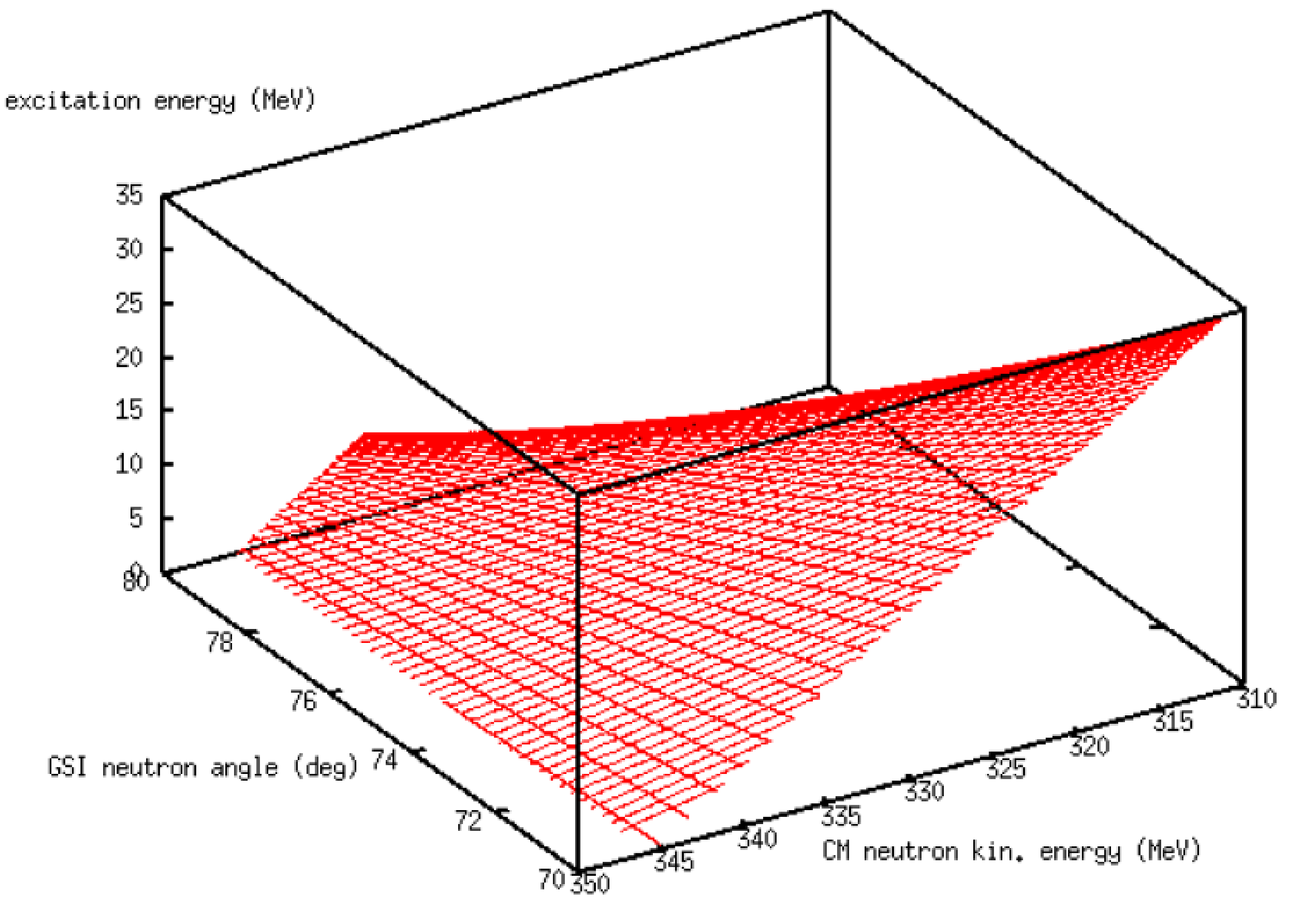

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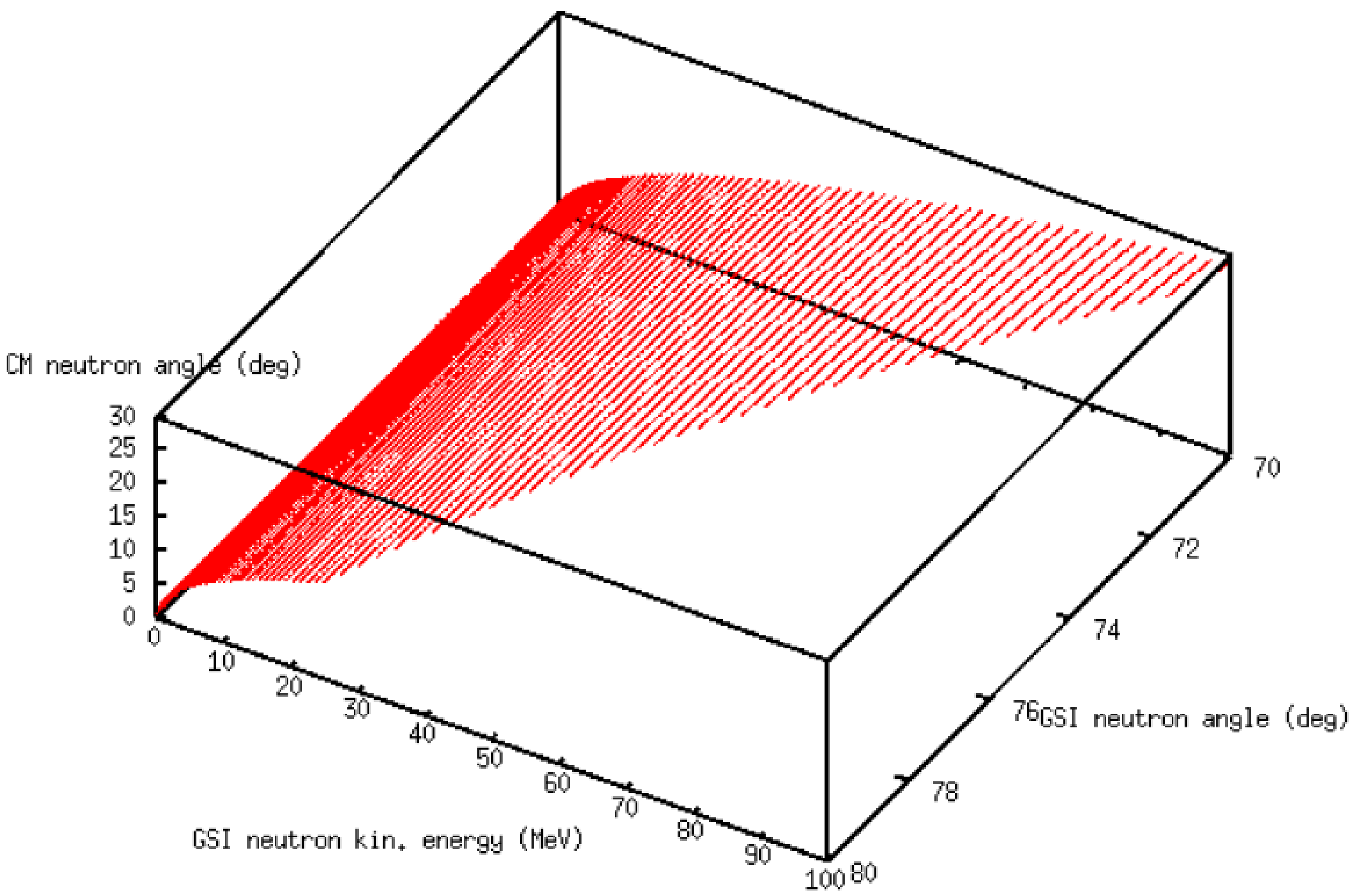

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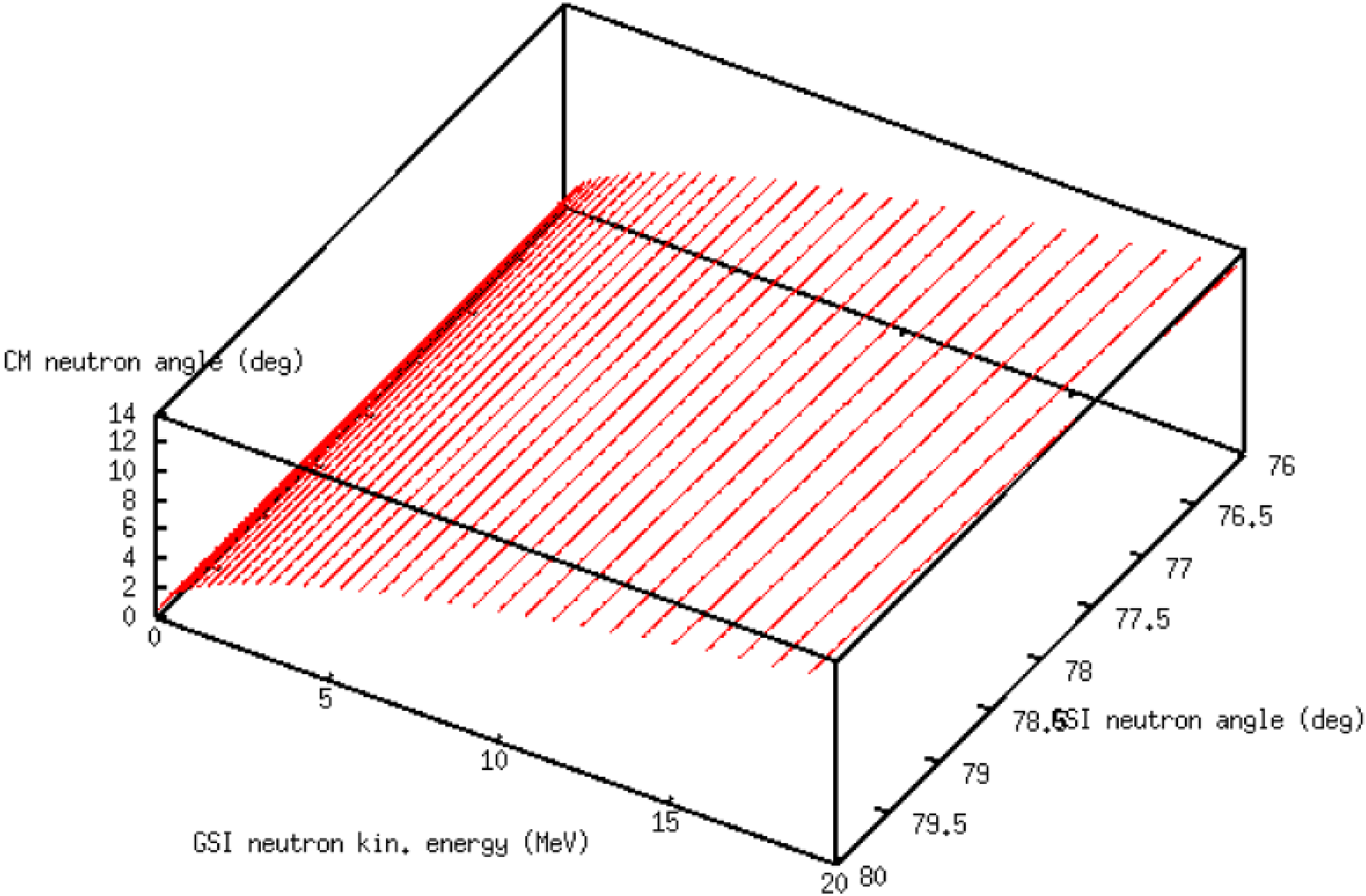
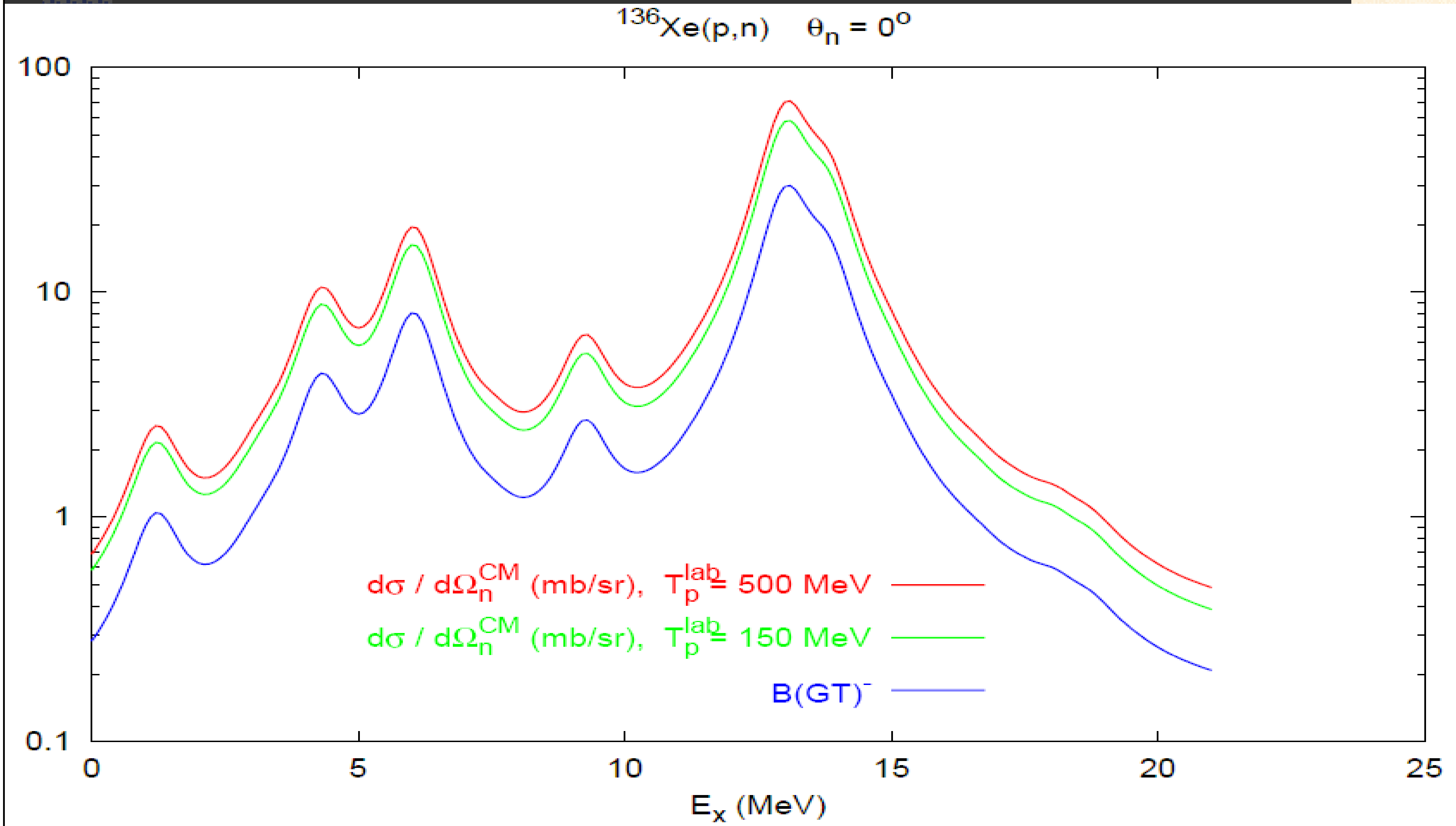


(p,n) cross-sections for ^{136}Xe have been generated



Summary

- Theoretical ingredients ready to confront TEST experiment in ^{136}Xe
- ***Elastic*** cross-sections produced with the effective interactions and folded with nuclear densities may (should!) be confronted with experimental data
- $^{136}Xe(p,n)$ cross-sections will be produced