Effects of level density a-parameter in the framework of preequilibrium model for ^{58}Ni (n, xp) reaction at 8, 9, 9.4 and 11 MeV

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I Introduction

- In this study, the calculations of proton emission spectra produced by ^{58}Ni (n, xp) reaction are used in the framework of preequilibrium model with the Talys code. The main purpose of this work is to investigate the sensitivity of level density a-parameter in the framework of preequilibrium model. Exciton model predictions were used, and some necessary parameters have been investigated for our calculations. The level density *a*-parameter affects strongly the fit for ^{58}Ni(n, xp) reaction and the comparison with experimental data shows clear improvement over the exciton model calculations.

II Theoretical models formula

Exciton model

One component model

Two-component model

Two-component model

Pre-equilibrium differential cross section

$$\frac{d\sigma_k^{PE}}{dE_k} = \sigma^{CF} \sum_{p_\pi = p_\pi^0}^{p_\pi^{max}} \sum_{p_\nu = p_\nu^0}^{p_\nu^{max}} W_k(p_\pi, h_\pi, p_\nu, h_{\nu,} E_k)\, \tau\,(p_\pi, h_\pi, p_\nu, h_\nu) \times \mathrm{P}\,(p_\pi, h_\pi, p_\nu, h_{\nu,})$$

Back-shifted Fermi gas Model (BFM)

$$\rho_F^{tot}(E_x) = \frac{1}{\sqrt{2\pi}\sigma}\frac{\sqrt{\pi}}{12}\frac{exp\left[2\sqrt{aU}\right]}{a^{1/4}U^{5/4}}$$

$$\rho_F(E_x, J, \Pi) = \frac{1}{2}\frac{2J+1}{2\sqrt{2\pi}\sigma^3}exp\left[-\frac{\left(J+\frac{1}{2}\right)^2}{2\sigma^2}\right]\frac{\sqrt{\pi}}{12}\frac{exp\left[2\sqrt{aU}\right]}{a^{1/4}U^{5/4}}$$

$$U = E_x - \Delta^{BFM}$$

$$\Delta^{BFM} = \chi\frac{12}{\sqrt{A}} + \delta \quad \text{with} \quad \chi = -1, \quad \text{for } odd - \text{odd},$$
$$= 0, \quad \text{for } odd - \text{even},$$
$$= 1, \quad \text{for } even - \text{even}$$

Level density (Fermi gas model)

$$a = a(E_x) = \tilde{a}\left(1 + \delta W \frac{1 - exp[-\gamma U]}{U}\right)$$

$\tilde{a}$ is the asymptotic level density $\tilde{a} = \alpha A + \beta A^{2/3}$

U is the effective excitation energy

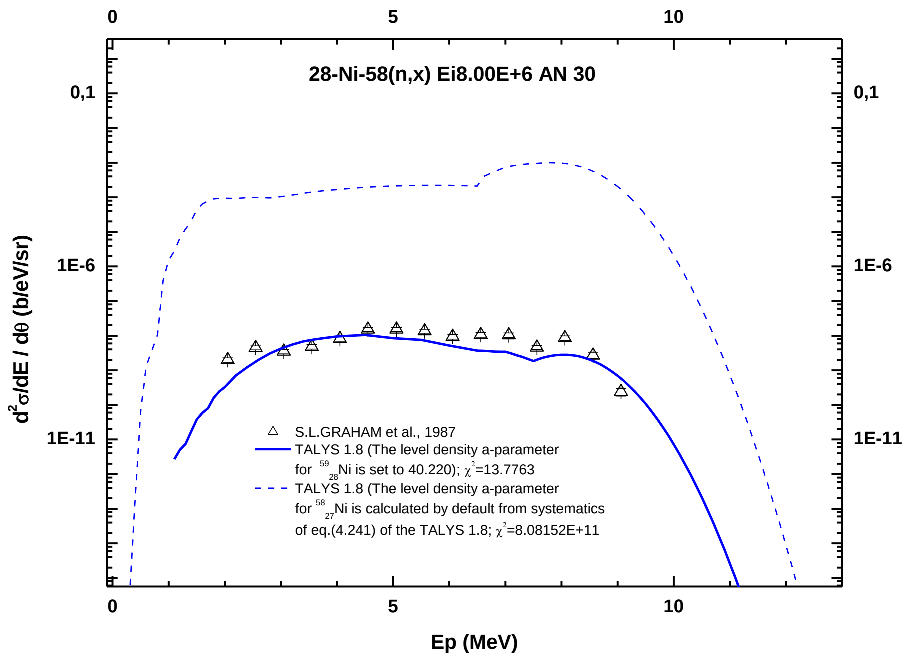
γ damping parameter γ

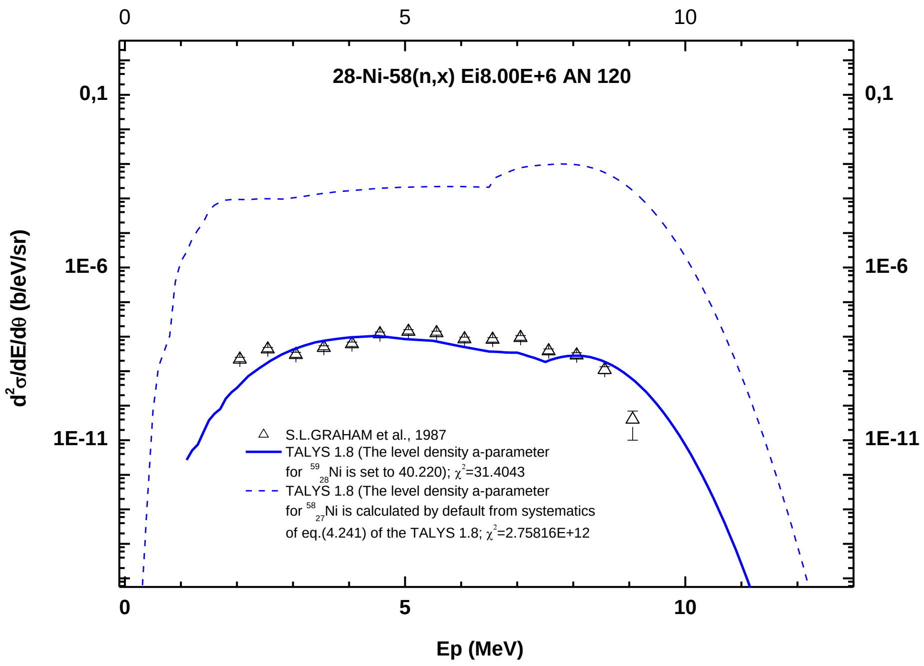
$$\gamma = \frac{\gamma_1}{A^{\frac{1}{3}}} + \gamma_2$$

Table I: **The principal input parameters used in the two-component exciton model calculations at the 8, 9.4 and 11 MeV neutron incident energies for (30◦, 60◦ and 120◦ angles emission), and at 9 MeV neutron incident energies for (51◦,79◦, 109◦ and 120◦ angles emission) and for angle integrated proton particle emission spectra by using Talys code.**

Optical potential	- Local and global nucleon optical models of Koning and Delaroche
Optical model parameters via adjustable local parameters(at the 8, 9.4 and 11 MeV neutron incident energies for (30°, 60° and 120° angles emission), at 9 MeV neutron incident energies (for 51◦,79◦, 109◦ and 141◦ angles emission) and for angle integrated proton particle emission spectra)	- v1adjust p 1.05
Fu's pairing energy correction	- Pairmodel 1
Parameterisation of the matrix element (at the 8 and 11 MeV neutron incident energies for (30°, 60° and 120° angles emission), and at 9 MeV neutron incident energies for (51◦,79◦, 109◦ and 141◦ angles emission) and for angle integrated proton particle emission spectra) Parameterisation of the matrix element (at the 9.4 MeV neutron incident energies for (30◦, 60◦ and 120◦ angles emission)	- M2constant =0,01 - M2constant = 0.05
Back Shifted Fermi Gas Model level density (at the 8, 9.4 and 11 MeV neutron incident energies for (30°, 60° and 120° angles emission), and at 9 MeV neutron incident energies for (51◦,79◦, 109◦ and 141◦ angles emission)	- Ldmodel2
Single-particle level density parameter g = A/Kph (at the 8, 9.4 and 11 MeV neutron incident energies for (30°, 60° and 120° angles emission), at 9 MeV neutron incident energies for (51◦,79◦, 109◦ and 141◦ angles emission) and for angle integrated proton particle emission spectra)	- Kph=44.

Level density a- parameter (at the 8, 9.4 and 11 MeV neutron incident energies for (30°, 60° and 120° angles emission), at 9 MeV neutron incident energies (for 51◦,79◦, 109◦ and 141◦ angles emission) and for angle integrated proton particle emission spectra)	- 40.220 MeV^{-1} in ${}^{59}_{28}Ni$ (compound nucleus) and 2.9 MeV^{-1} in ${}^{58}_{27}Ni$ (residual nucleus) at 8 MeV neutron incident energies for (30°, 60° and 120° angles emission); - 23.5 MeV^{-1} in ${}^{59}_{28}Ni$ (compound nucleus) and 2.9 MeV^{-1} in ${}^{58}_{27}Ni$ (residual nucleus) at 9.4 MeV neutron incident energies for (30°, 60° and 120° angles emission); - 53. MeV^{-1} in ${}^{59}_{28}Ni$ (compound nucleus) and 4.7 MeV^{-1} in ${}^{58}_{27}Ni$ (residual nucleus) at 11 MeV neutron incident energies for (30°, 60° and 120° angles emission); - 30. MeV^{-1} in ${}^{59}_{28}Ni$ (compound nucleus) and 3.1 MeV^{-1} in ${}^{58}_{27}Ni$ (residual nucleus) at 9 MeV neutron incident energies for (51◦,79◦, 109◦ and 141◦ angles emission); - 30. MeV^{-1} in ${}^{59}_{28}Ni$ (compound nucleus) and 3.1 MeV^{-1} in ${}^{58}_{27}Ni$ (residual nucleus) at 9 MeV for angle integrated proton particle emission spectra;





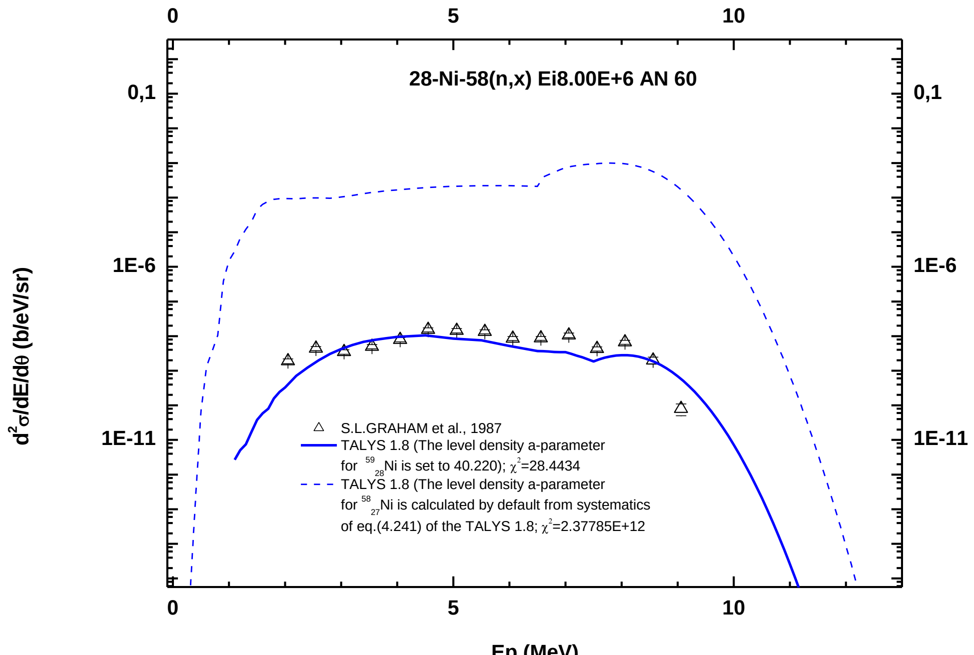
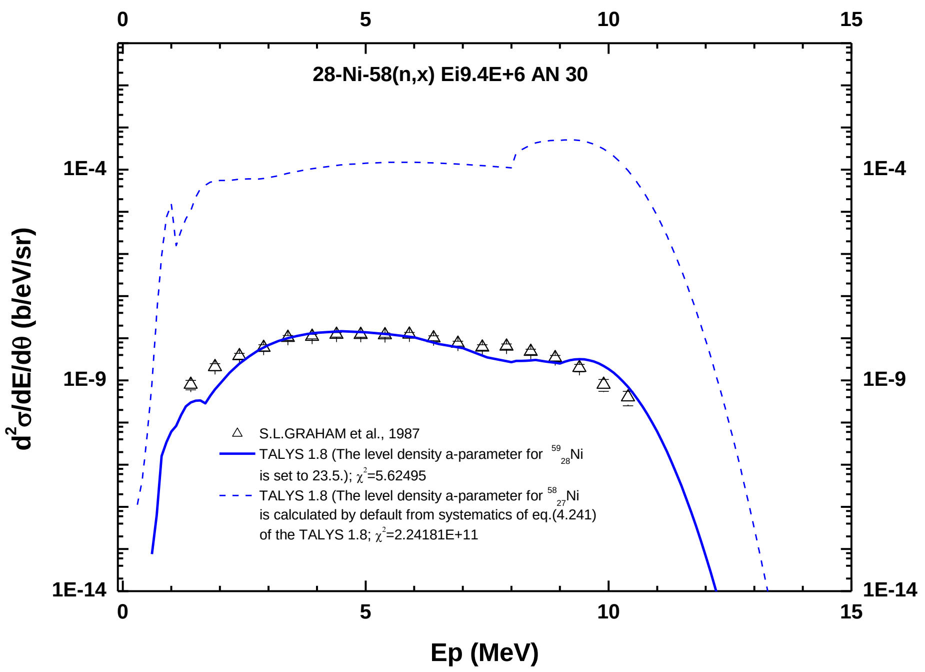
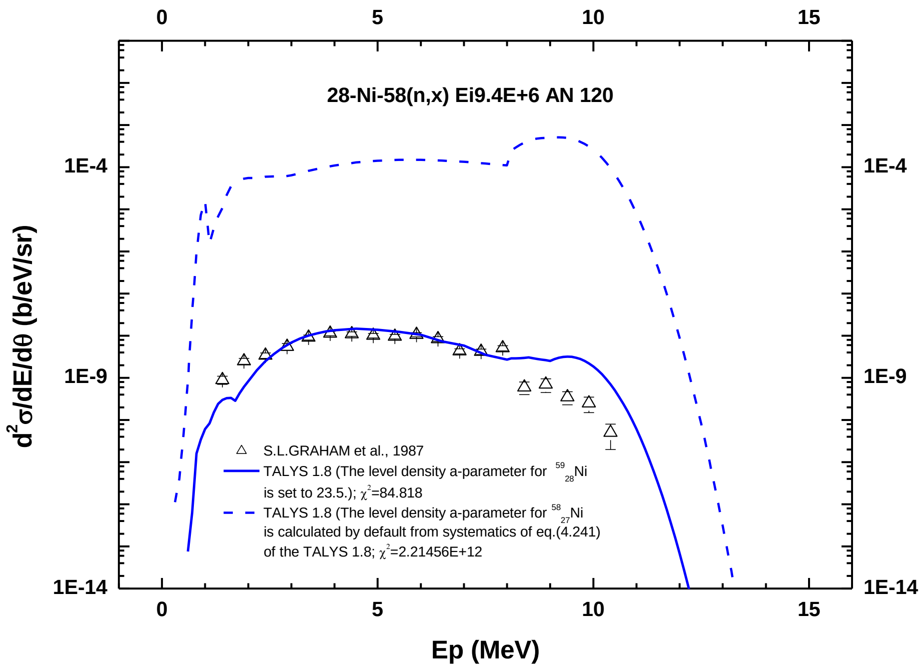


Fig. 1. Comparison between double differential cross sections as calculated with the effect of the level density parameter-a of Back Shifted Fermi Gas Model level density (Dilg et al., 1973) (continuous and dotted blue lines) at the 8 MeV neutron incident energie (for 30◦, 60◦ and 120◦ angles emission), by using TALYS 1.8 code (Koning et al., 2007) to the experimental data (solid squares) (GRAHAM et al., 1987).





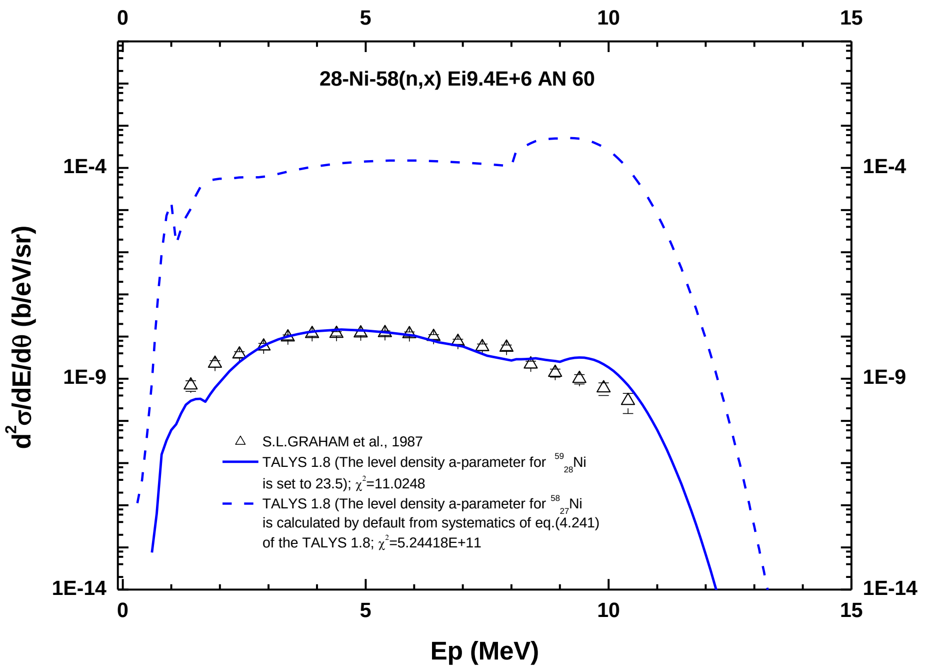
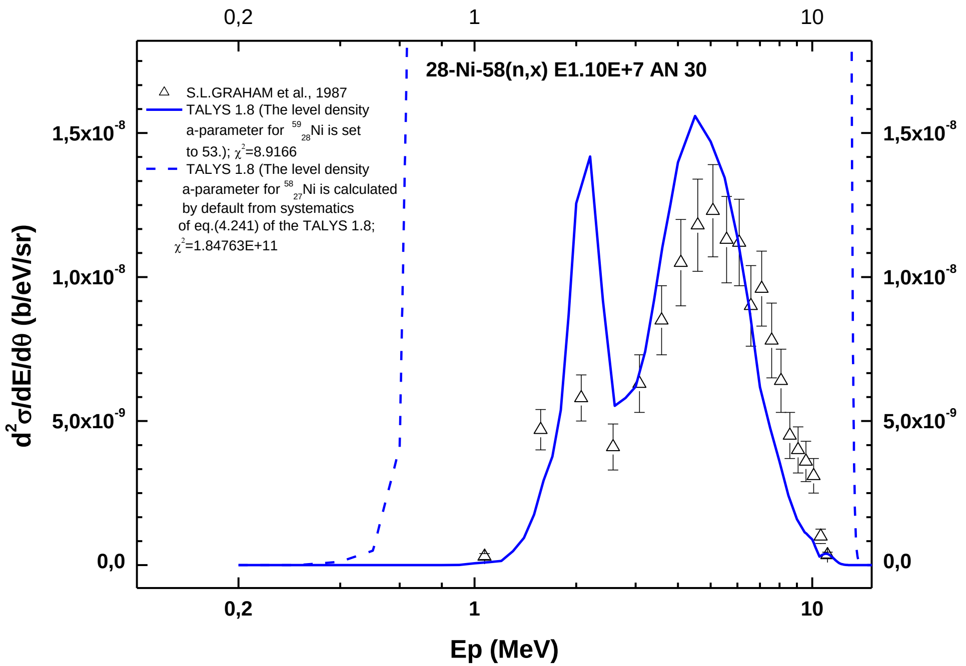
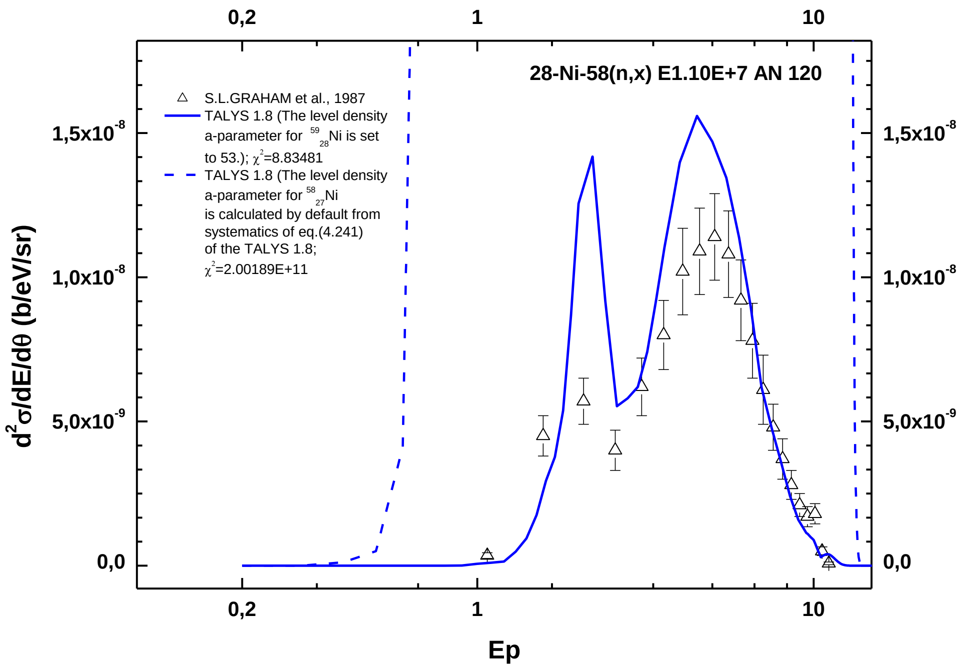


Fig. 2. Comparison between double differential cross sections as calculated with the effect of the level density parameter-a of Back Shifted Fermi Gas Model level density (Dilg et al., 1973) (continuous and dotted blue lines) at the 9,4 MeV neutron incident energie (for 30◦, 60◦ and 120◦ angles emission), by using TALYS 1.8 code (Koning et al., 2007) to the experimental data (solid squares) (GRAHAM et al., 1987).





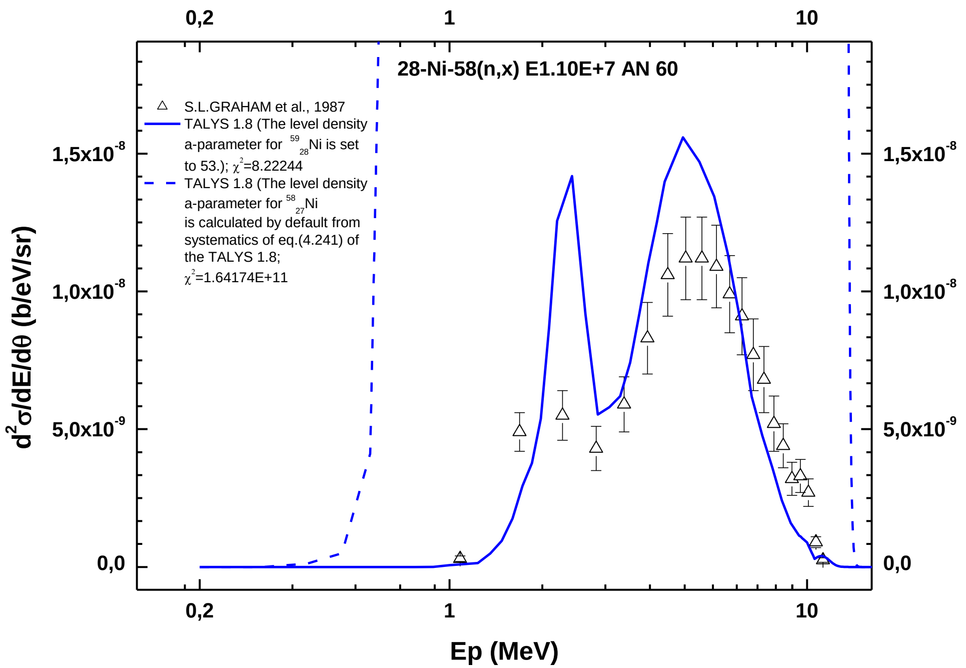


Fig. 3. Comparison between double differential cross sections as calculated with the effect of the level density parameter-a of Back Shifted Fermi Gas Model level density (Dilg et al., 1973) (continuous and dotted blue lines) at the 11. MeV neutron incident energie (for 30◦, 60◦ and 120◦ angles emission), by using TALYS 1.8 code (Koning et al., 2007) to the experimental data (solid squares) (GRAHAM et al., 1987).

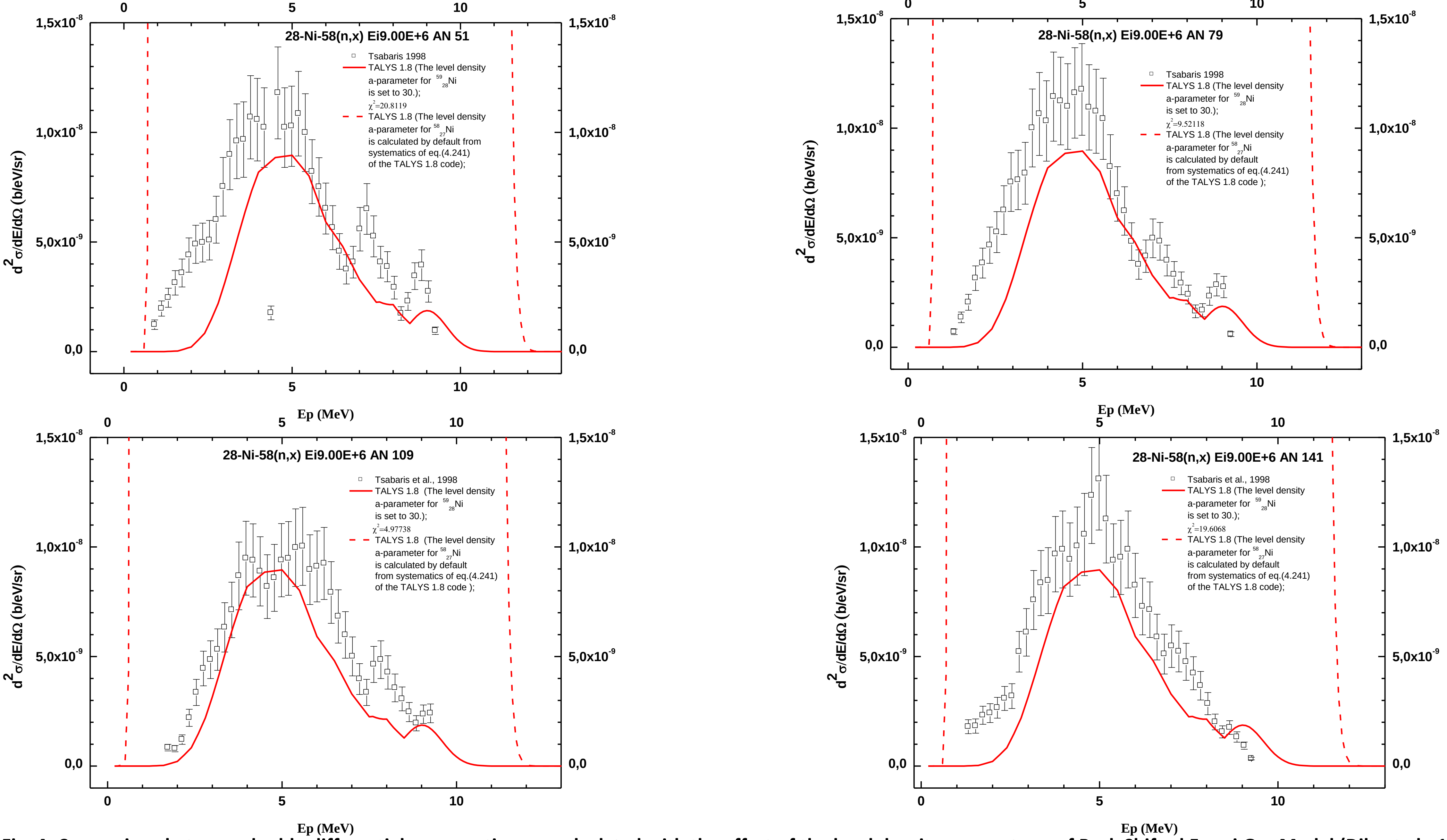


Fig. 4. Comparison between double differential cross sections as calculated with the effect of the level density parameter-a of Back Shifted Fermi Gas Model (Dilg et al., 1973) level density (continuous and dotted red lines) at the 9.4 MeV neutron incident energie (for 51◦, 79◦, 109◦ and 141◦ angles emission) by using TALYS 1.8 code (Koning et al., 2007) to the experimental data (open squares) (Tsabaris et al., 1998).

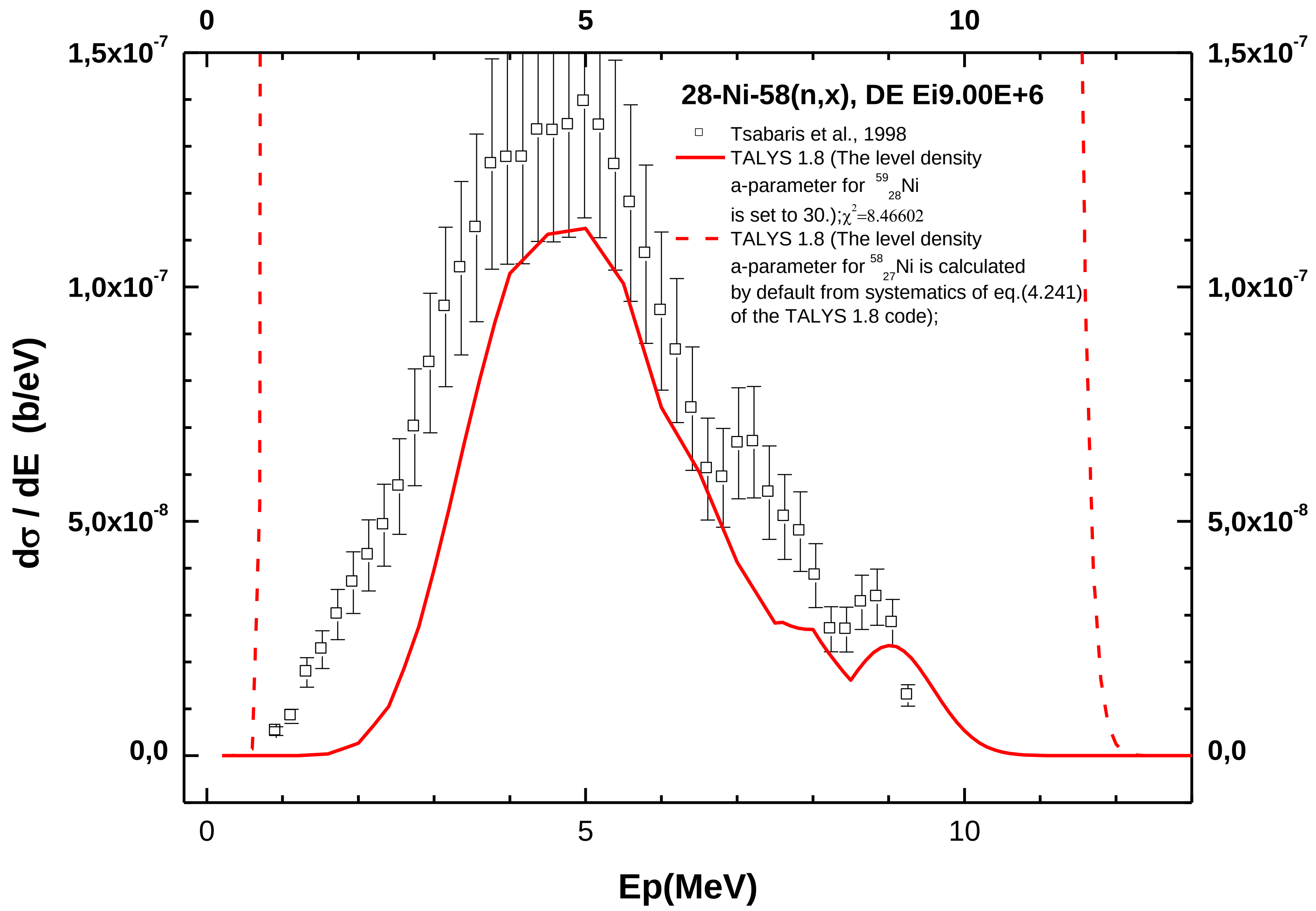


Fig. 5. Comparison between calculated angle integrated proton particle emission spectra with the level density parameter-a of Back Shifted Fermi Gas Model (Dilg et al., 1973) level density by using TALYS 1.8 code (Koning et al., 2007) (continuous and dashed red lines) for ^{58}Ni(n, xp) to the experimental data (open squares) (Tsabaris et al., 1998) from 9 MeV neutron induced.

Conclusion

We have analyzed the calculated double differential cross sections and angle-integrated calculations of (n, xp) reactions on nickel ^{58}Ni target using nuclear reaction model in TALYS 1.8 code. Our results show that the calculations of the pre-equilibrium in terms of exciton model at two components (in TALYS code), and the different values of the level density parameter a in residual nucleus and compound nucleus for ^{58}Ni (n, xp) reaction show the similar behavior with the experimental data. For all the figures as shown in this work, the TALYS code results are close to the experimental results and the lower χ^2 value give a significantly better fit when compared to the experimental results. We will validate our new nuclear data for neutron induced reaction on isotopes of chromium and iron with criticality and shielding benchmarks.

Thank you for your attention