Applying TalysLib library for optimization of optical potential parameters for neutron scattering on ^{24}Mg and ^{32}S

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TANGRA project

Project "TANGRA" (TAgged Neutrons & Gamma-RAys) [1] at JINR-FLNP (Dubna) is aimed at studying nuclear reactions caused by fast neutrons.

As a source of neutrons a VNIIA portable neutron generator ING-27 (Fig.1) is used [2]. The 14.1 MeV neutrons are produced in d-t fusion reaction:

$$d + t \longrightarrow \alpha + n,\ Q = 17.59\ \text{MeV}$$

The built-in ING-27 neutron tube 64-pixel α-detector allows to "tag" and count neutrons, because the both reaction products are emitted nearly collinear in opposite directions.

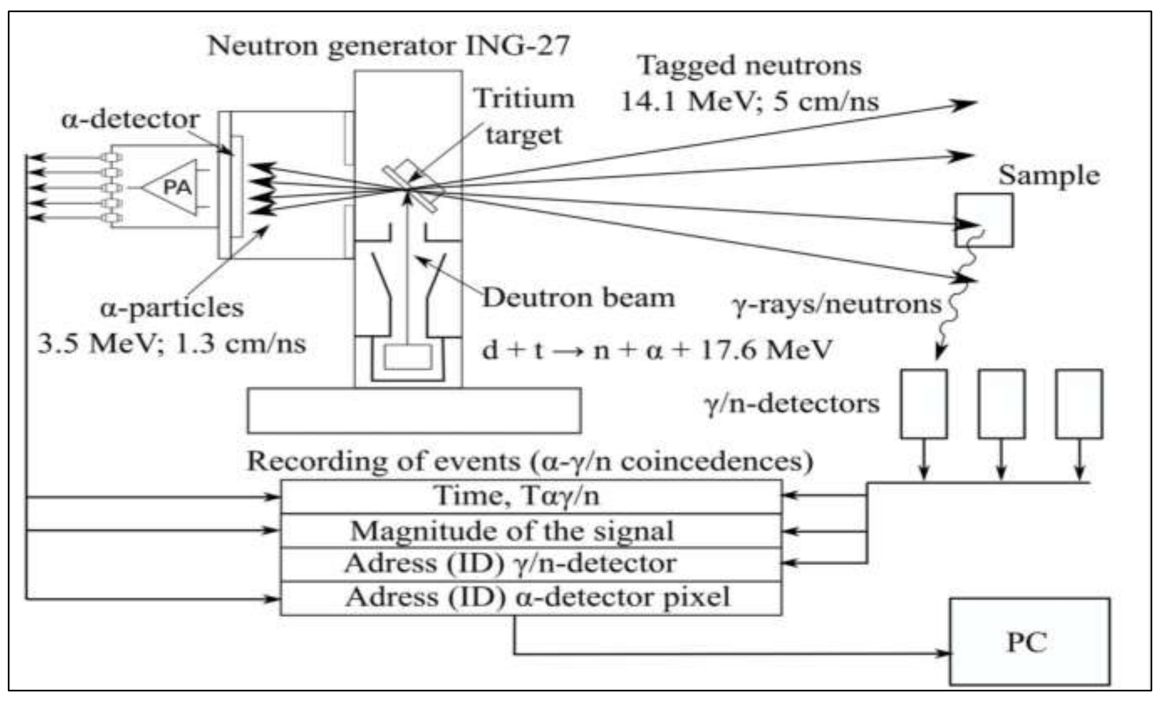

Fig.1. General scheme for TANGRA experimental setup.

TalysLib (https://github.com/terawatt93/TalysLib)

For the purposes of theoretical part of the project, the TALYS [3] program is used. It is a powerful nuclear reaction calculation program which uses RIPL-3 database. To simplify access to the calculation results and the TALYS database, as well as ENDF and EXFOR [4] databases, TalysLib is being developed.

TalysLib is an object-oriented C++ library. Its structure (Fig.2) groups nuclear data to C++ classes which are correspond to real physical objects and each object has a pointer to parent one.

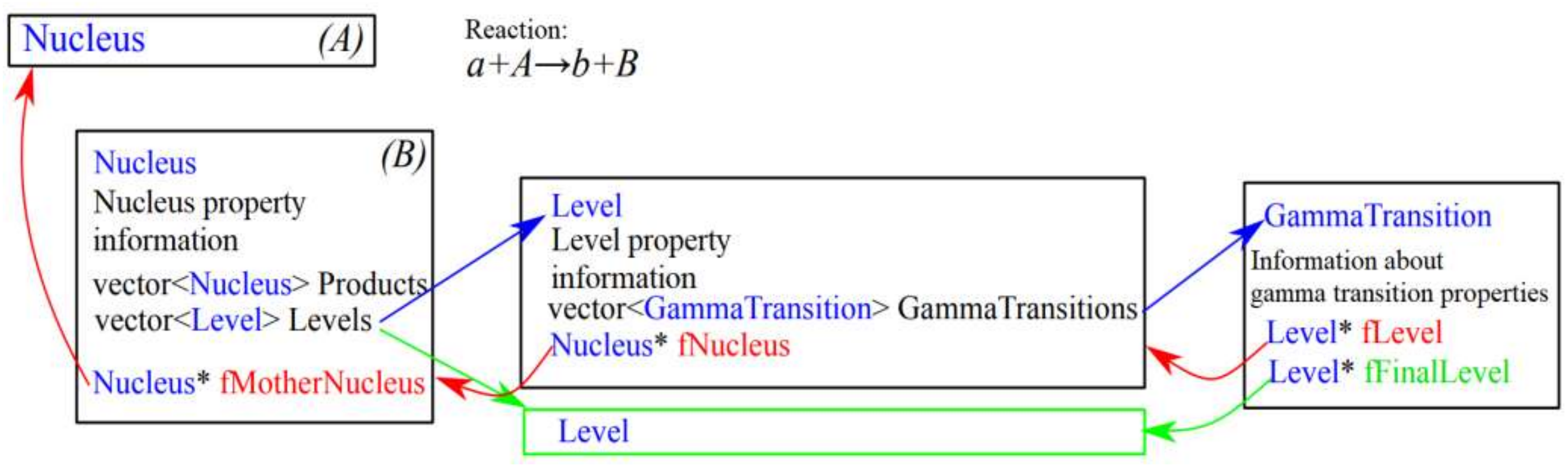

Fig.2. TalysLib structure.

Model parameters adjustment

TalysLib can be used model parameters search to improve agreement of the reactions parameters, calculated in TALYS, with experimental data using the χ^2 method. This functionality is implemented in the TalysFitterMT class and uses MINUIT minimizer built into ROOT. The minimization procedure is presented in the Fig.3.

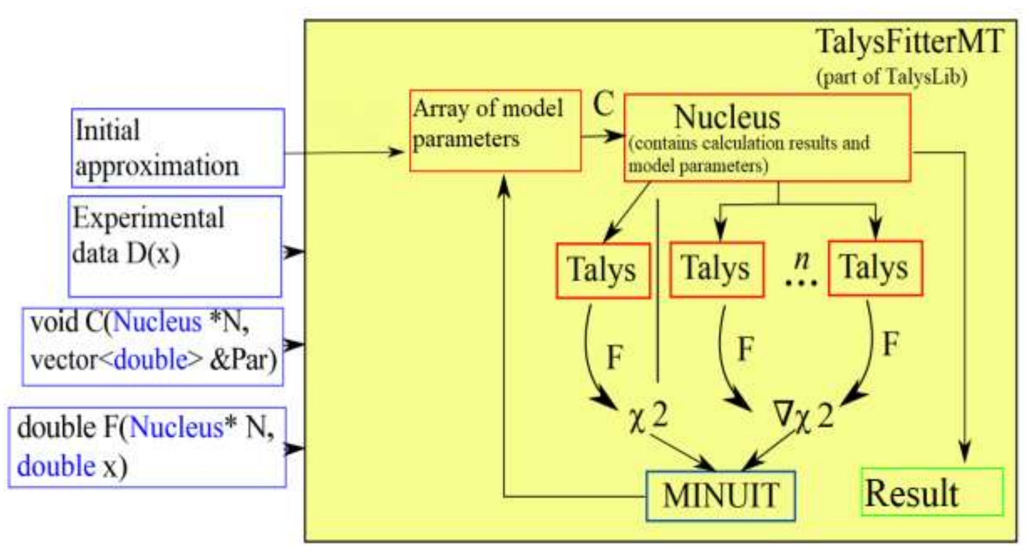

Fig.3. Block diagram of the minimization procedure.

The experimental data should be represented as *D(x)* function, where *x* is a parameter unique for each data point (like number, angle, etc). Function *C* connects the model parameters and minimization parameters. *F* returns calculation results for each data point with parameter *x* and used for the gradient calculations in multithreaded mode.

Experimental data extraction

The EXFOR is the most complete neutron reaction database nowadays, but its files are quite complex to read. We compared existed tabular formats that are already been created based on EXFOR: C4 [5] and EXFORTABLES [6]. In our analysis, we noticed errors in identification of the type of reaction. We were able to fix this for C4 format and create our own experimental database based on this format.

Optical model fit for ^{24}Mg

For our calculations we use symmetric rotator model and deformation parameters from TALYS default files. All experimental data was obtained from EXFOR with usage of TalysLib library in neutron energy diapason from 14.6 to 14.8 MeV.

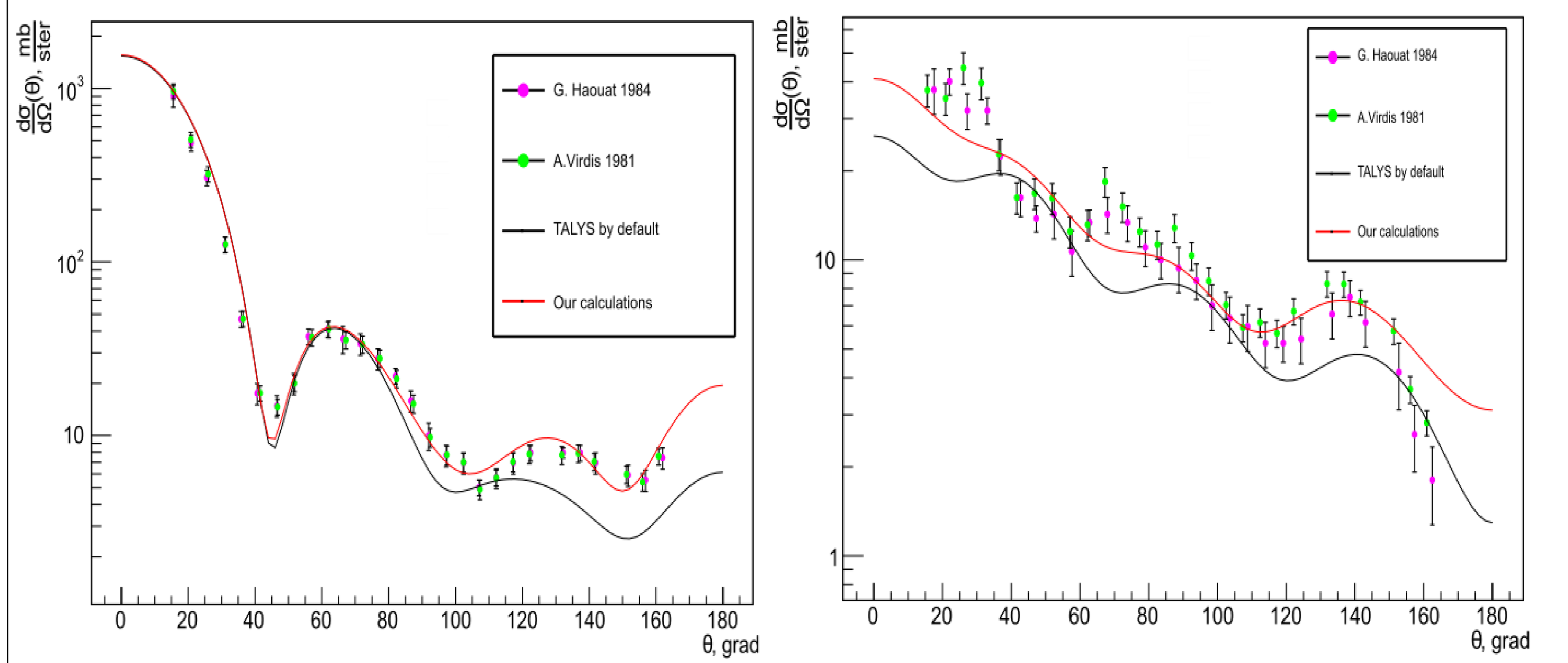

Fig.4. Result of the optical model fit of our experimental dataset: ^{24}Mg(*n,n*) *(left) and* ^{24}Mg(*n,n'*) ($\chi^2/N = 3.91$)

V_V MeV	W_V MeV	W_D MeV	V_{SO} MeV	W_{SO} MeV	r_V fm	a_V fm	r_D fm	a_D fm	r_{SO} fm	a_{SO} fm	β_2	γ	β_4
48.70	1.286	7.63	5.413	-0.07	1.163	0.674	1.296	0.54	0.96	0.59	0.592	20	-0.05

Optical model parameters of TALYS 1.9 by default.

V_V MeV	W_V MeV	W_D MeV	V_{SO} MeV	W_{SO} MeV	r_V fm	a_V fm	r_D fm	a_D fm	r_{SO} fm	a_{SO} fm	β_2	γ	β_4
48.36	0.971	4.79	4.735	0	1.167	0.633	1.349	0.70	0.85	0.58	0.579	20	-0.107

Optical model parameters gained from fit of experimental data.

Optical model fit for ^{32}S

For our calculations we use vibration model and deformation parameters from TALYS default files. All experimental data was obtained from EXFOR with usage of TalysLib library in neutron energy diapason from 13.9 to 14.3 MeV.

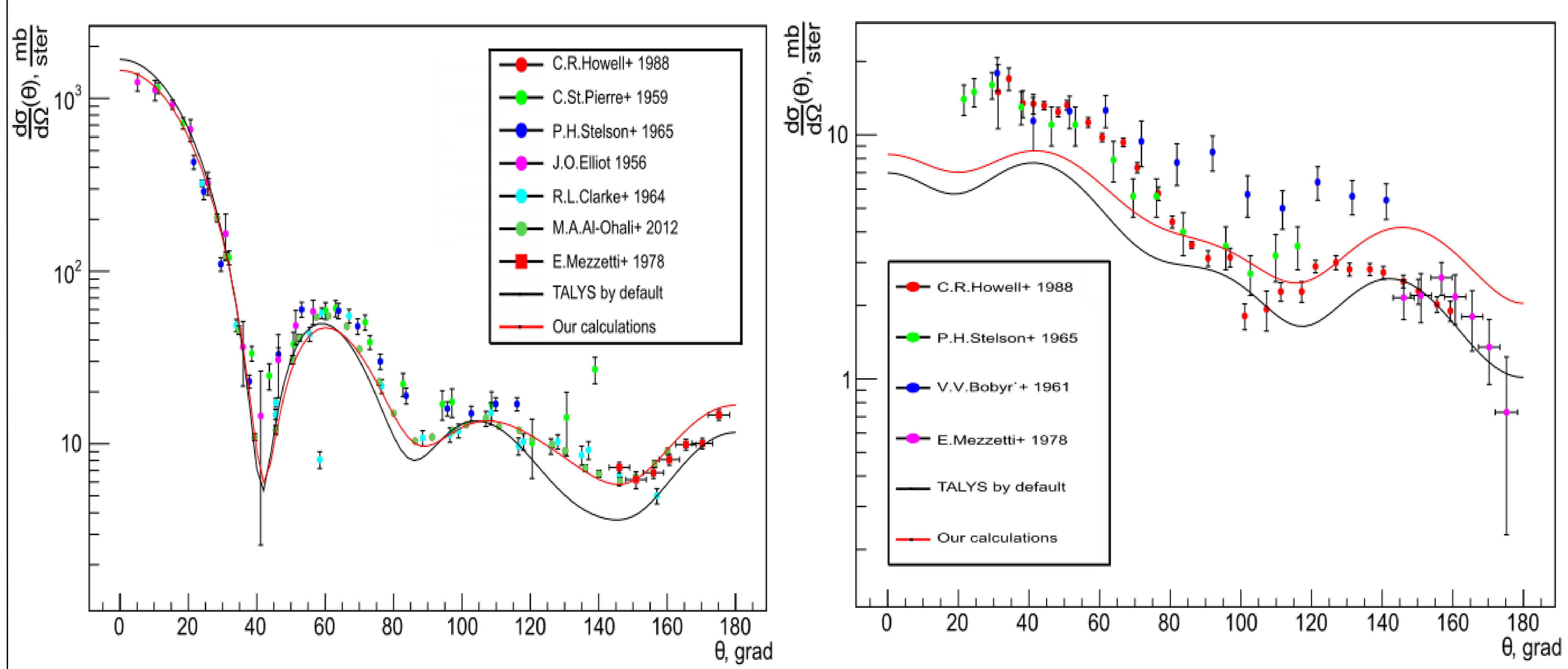

Fig.5. Result of the optical model fit of our experimental data: ^{32}S(*n,n*) *(left) and* ^{32}S(*n,n'*) ($\chi^2/N = 19.97$)

V_V MeV	W_V MeV	W_D MeV	V_{SO} MeV	W_{SO} MeV	r_V fm	a_V fm	r_D fm	a_D fm	r_{SO} fm	a_{SO} fm	β_2
48.89	1.20	7.68	5.46	-0.07	1.18	0.67	1.29	0.54	0.98	0.59	0.299

Optical model parameters of TALYS 1.9 by default.

V_V MeV	W_V MeV	W_D MeV	V_{SO} MeV	W_{SO} MeV	r_V fm	a_V fm	r_D fm	a_D fm	r_{SO} fm	a_{SO} fm	β_2
50.60	0.93	4.78	7.62	0	1.17	0.58	1.14	0.76	0.83	1.0	0.316

Optical model parameters gained from fit of experimental data.

Conclusions

A new functional for experimental data extraction from EXFOR was added to TalysLib. Based on the obtained experimental data we optimize optical model and deformation parameters for ^{24}Mg and ^{32}S. We used TALYS global parametrization as initial values and assumed that first exited states can be described in terms of asymmetric rotator for ^{24}Mg and oscillator for ^{32}S. The most significant changes where noticed for depths of the imaginary part of the optical potential and surface and spin-orbital components of diffusion. Deformation parameters have not changed that much. The optical model parameters optimization improved agreement between calculation and experiment significantly.

References

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