Results from the PACE4 code for fusion evaporation reaction cross- section calculations

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Motivation

- **Lack of Information about cross section calculation**
- **Define the limits of the PACE4 code for different reactions**

LISE++

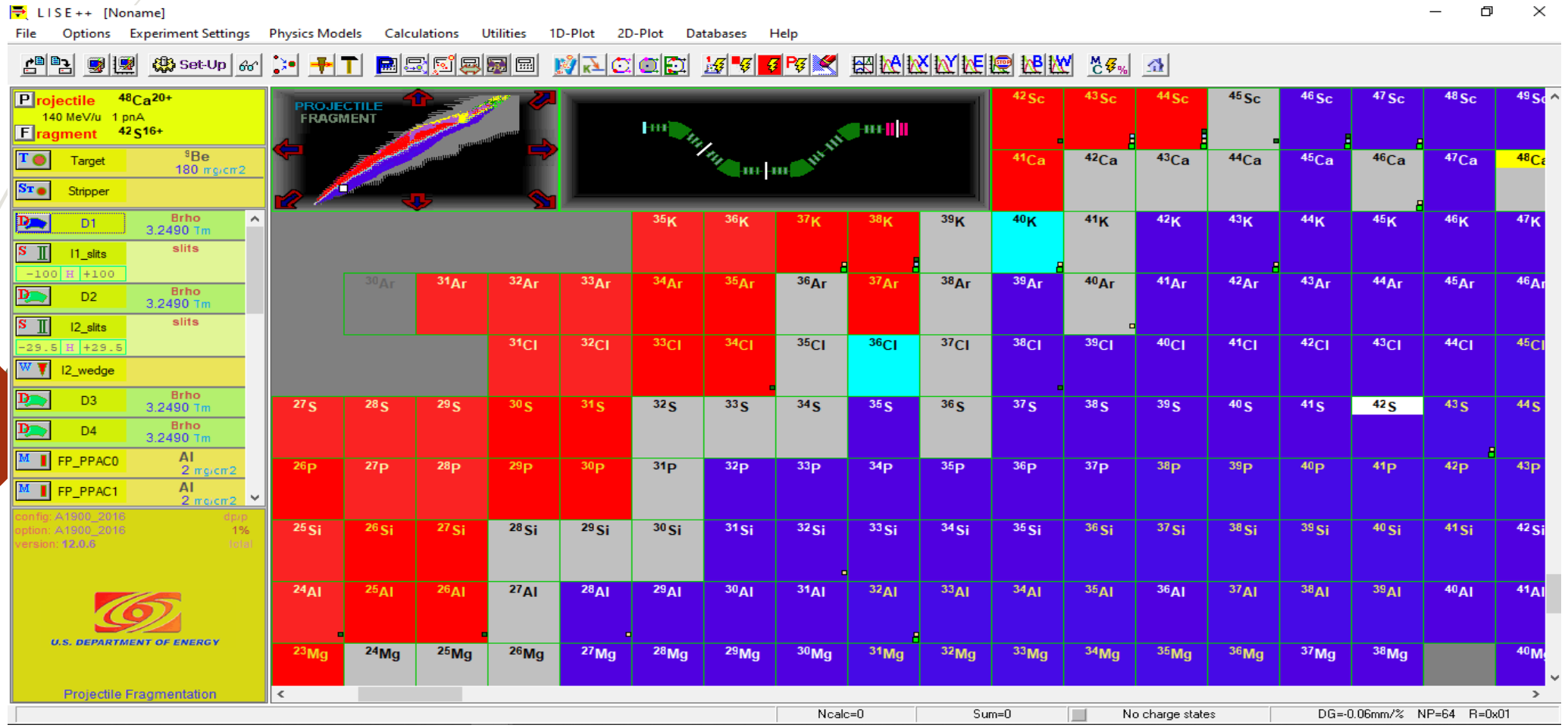
The program LISE is a kind of simulation program that can be used to produce radioactive beam via disintegration of nuclei or fusion evaporation

Aim of this program;

- Calculate the transmission and yields of disintegrated products.
- The program, can be able to simulate the production of radioactive beams regarding the parameters of the reaction mechanism up to the detection of nuclei that are selected by the fragment separator.

The program LISE++ plays a role in the development of fragment separators as well as the planning of experiments at different laboratories around the World.

The program is constantly expending and evolving using the feedback of users around the world. Many "satellite" tools have been incorporated into the LISE++ framework, which are accessible with buttons on the main toolbar.



PACE4
(Projection Angular-momentum Coupled Evaporation)

Fusion reactions can be simulated by using PACE4, code which is based on paper by A. Gavron and is advanced edition of JULIAN- the Hillman-Eyal evaporation code in the LISE++ framework.

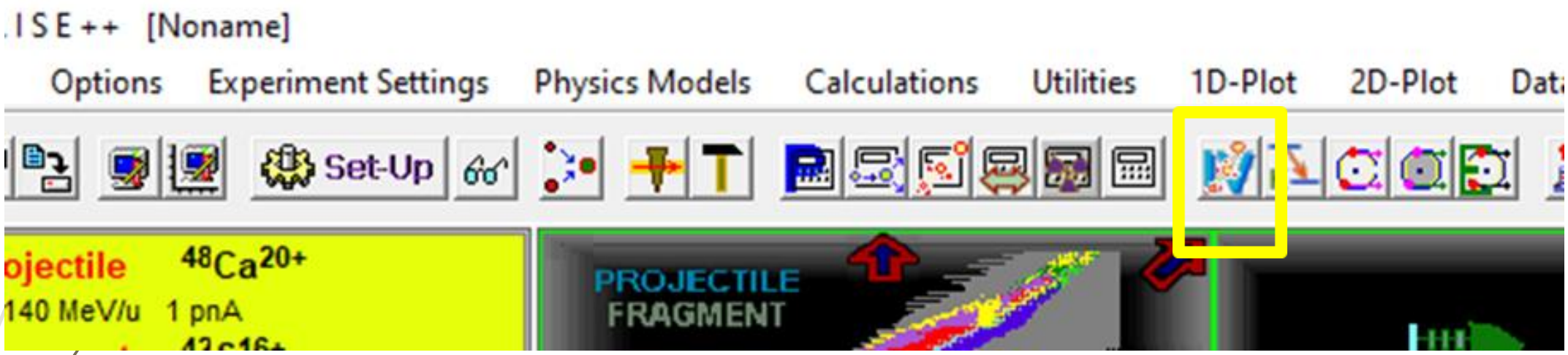
PACE4

- The PACE4 code is a statistical model evaporation code

- By using the Monte-Carlo simulation for de-excitation of compound nucleus, main evaporation channels can be simulated at different beam energies.

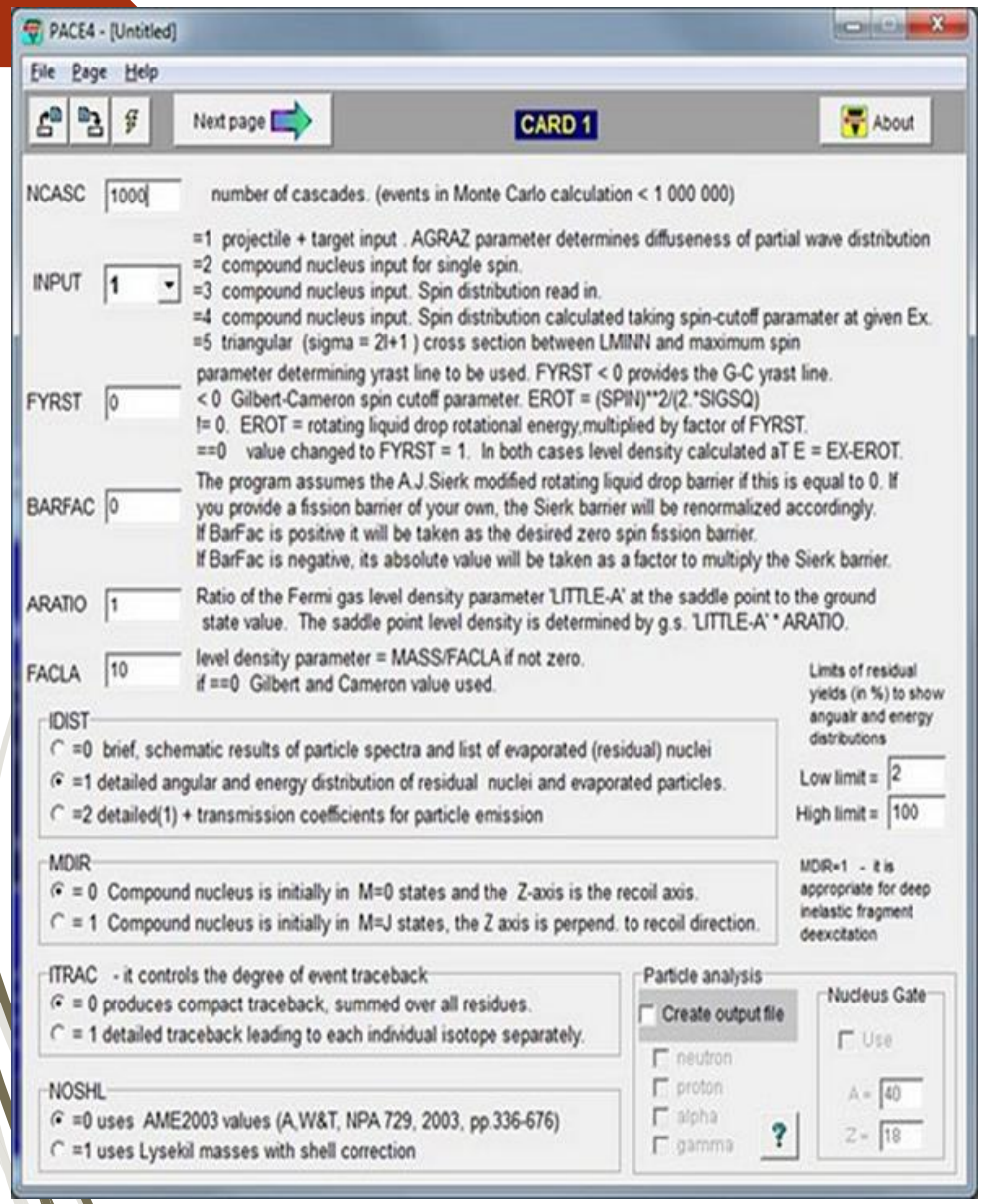
The main advantages of Monte-Carlo simulation is that it will provide correlation between various quantities. The code calculates probabilities and decay widths for all the nuclei which are present in the decay chain.

PACE4 in PRACTICE



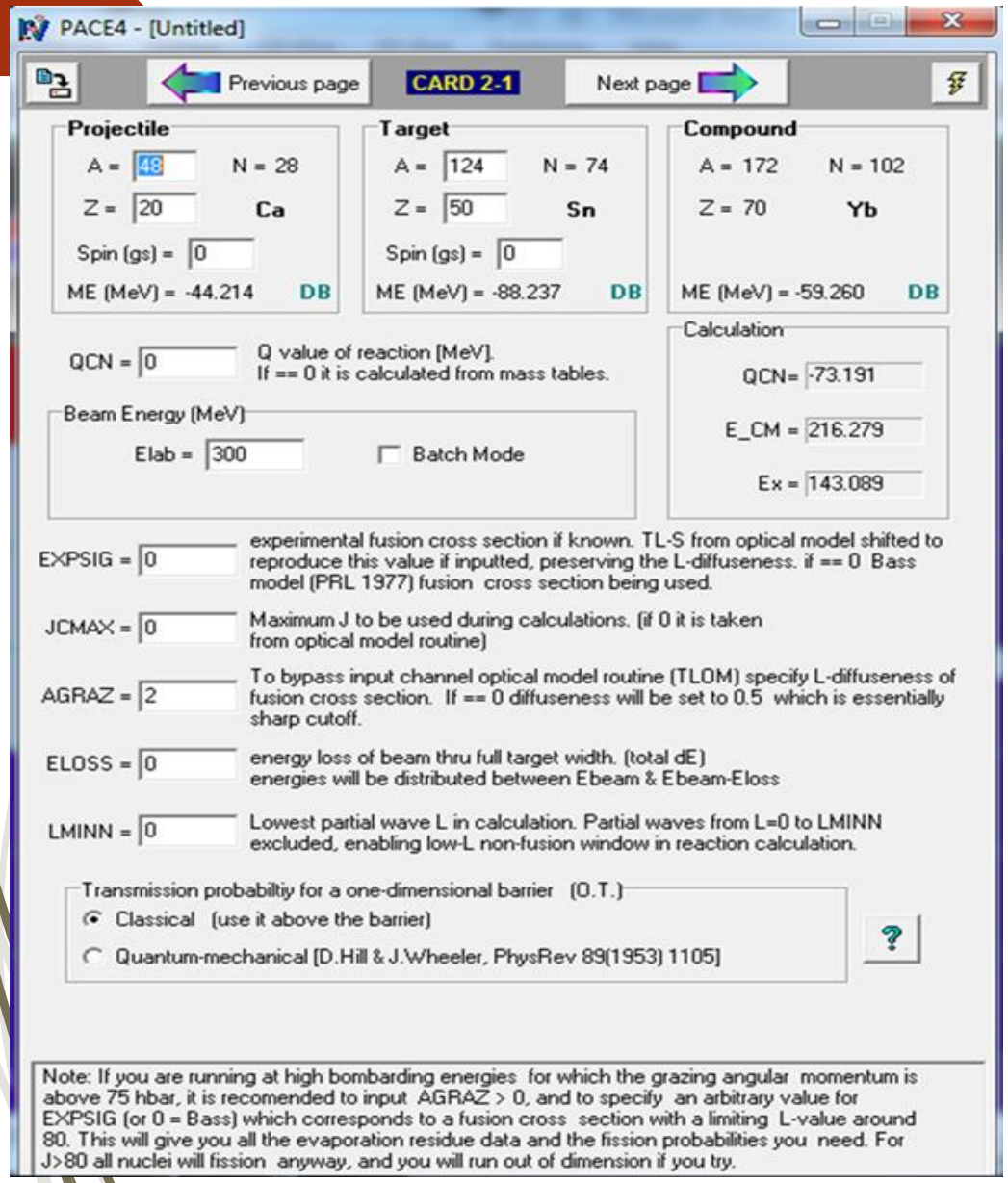
There is a shortcut for PACE4 in the toolbar of LISE++ program which is marked in figure below.

The first card of the PACE4 code



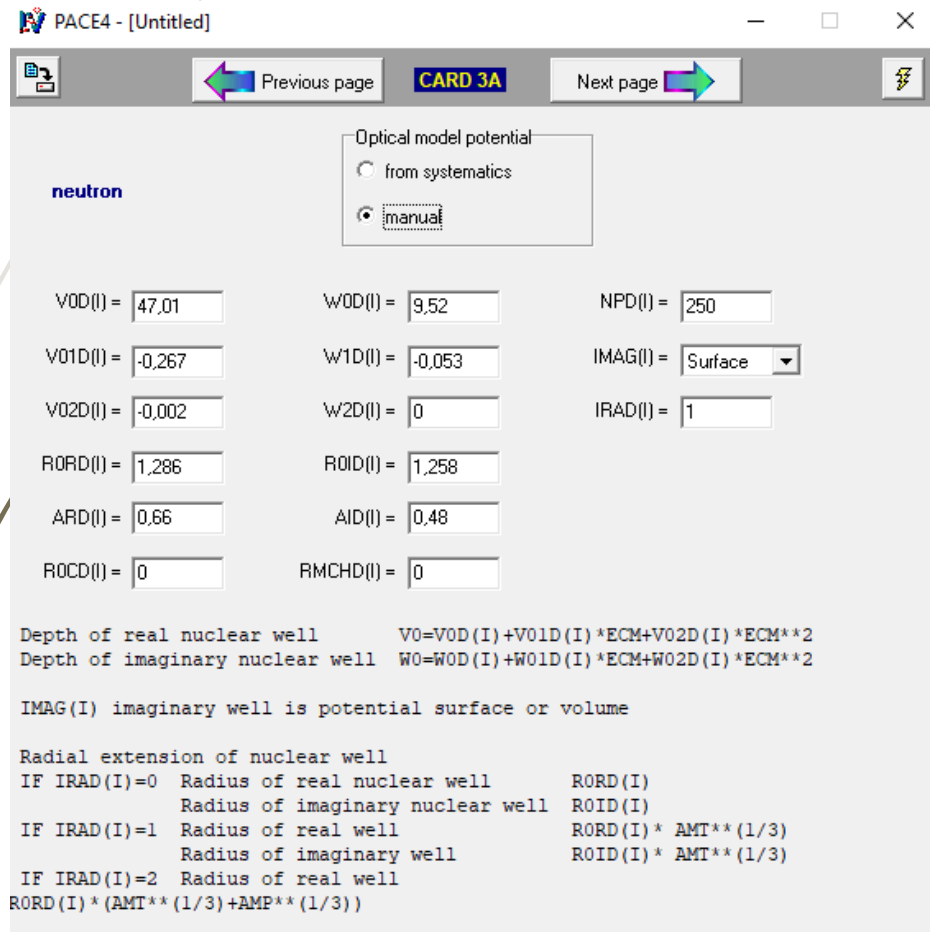
- NCASC stands for number of cascades for example number of events in Monte-Carlo calculations up to 1000000.
- INPUT will have values from 1 to 5, 1 for projectile and target input
- FACLA is level density parameter and in this version of PACE4 is taken as equal to 10 as default
- The yrast parameter is taken as unity.
- IDIST should be greater than 0 for particle analysis. Briefly , schematic results of particle spectra and list of evaporated (residual) nuclei

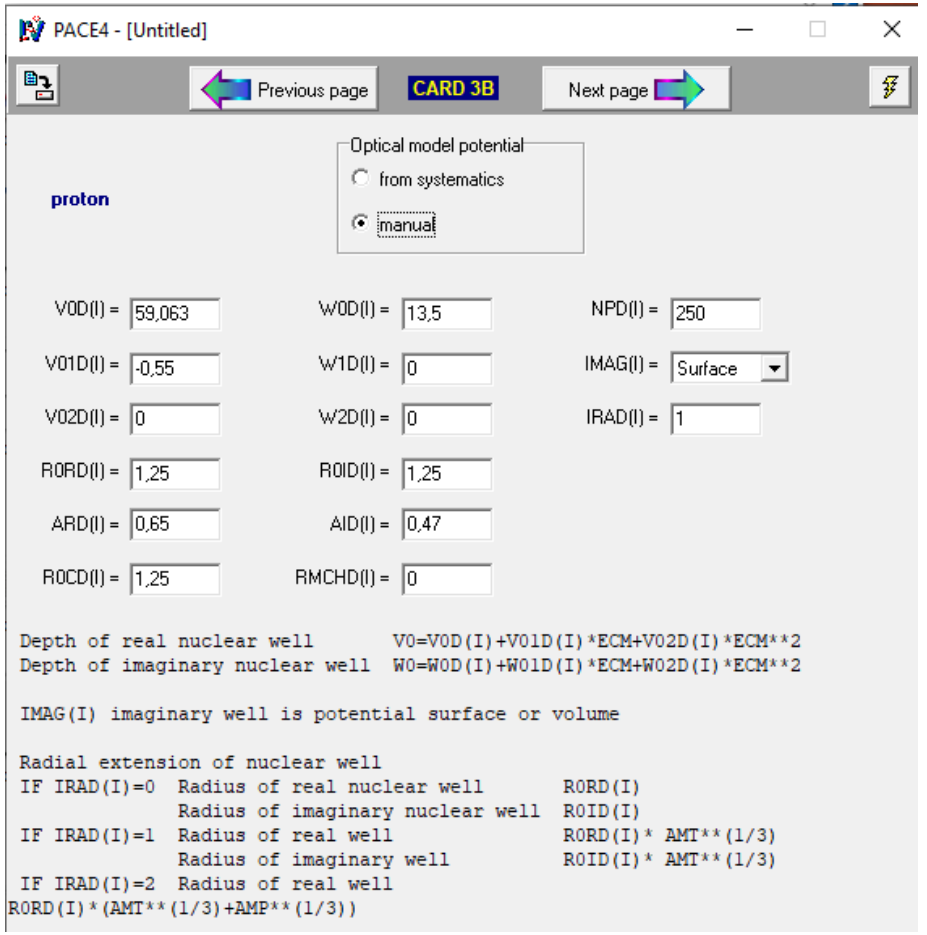
Second card of PACE4



- A and Z of projectile and target represent for mass number and atomic number respectively.
- Beam energy is in MeV; E_{lab} stands for energy value for which simulation is to be carried out.
- AGRAZ parameter should be taken equal to 2 for this version of PACE4
- *classical model* at above-barrier energies and *quantum mechanically* at sub-barrier energies

if calculations are not desired as default, optical model parameters can put on cards from 3A to 3D by manuel





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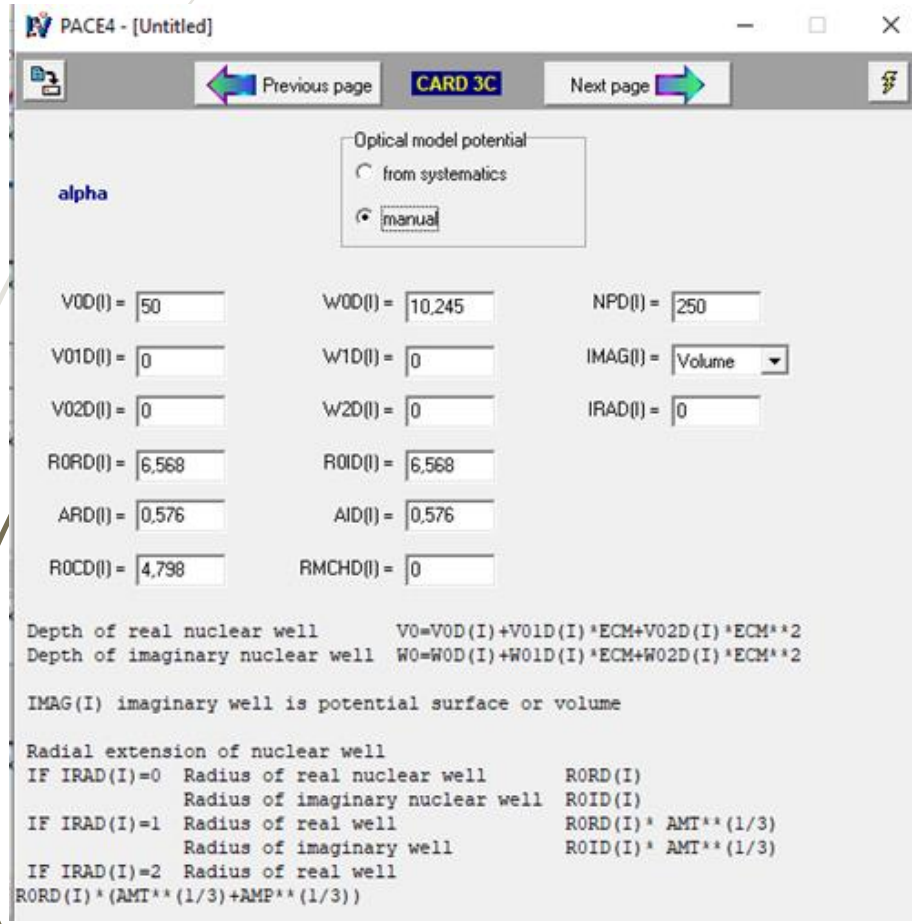
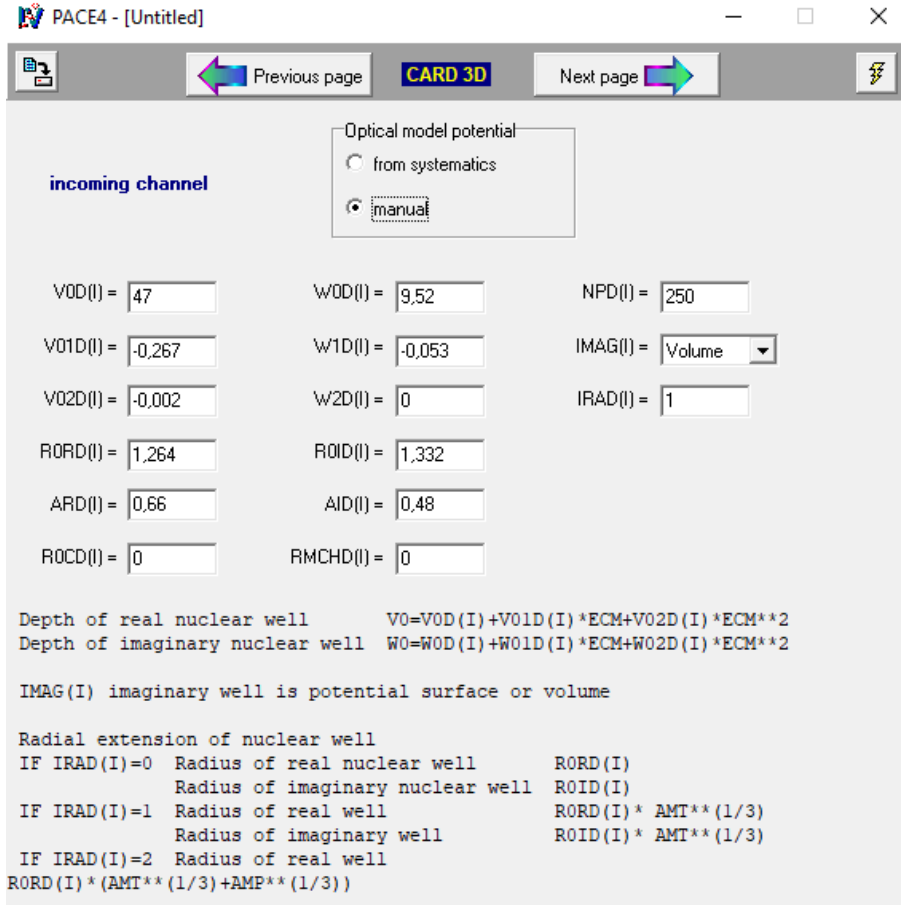
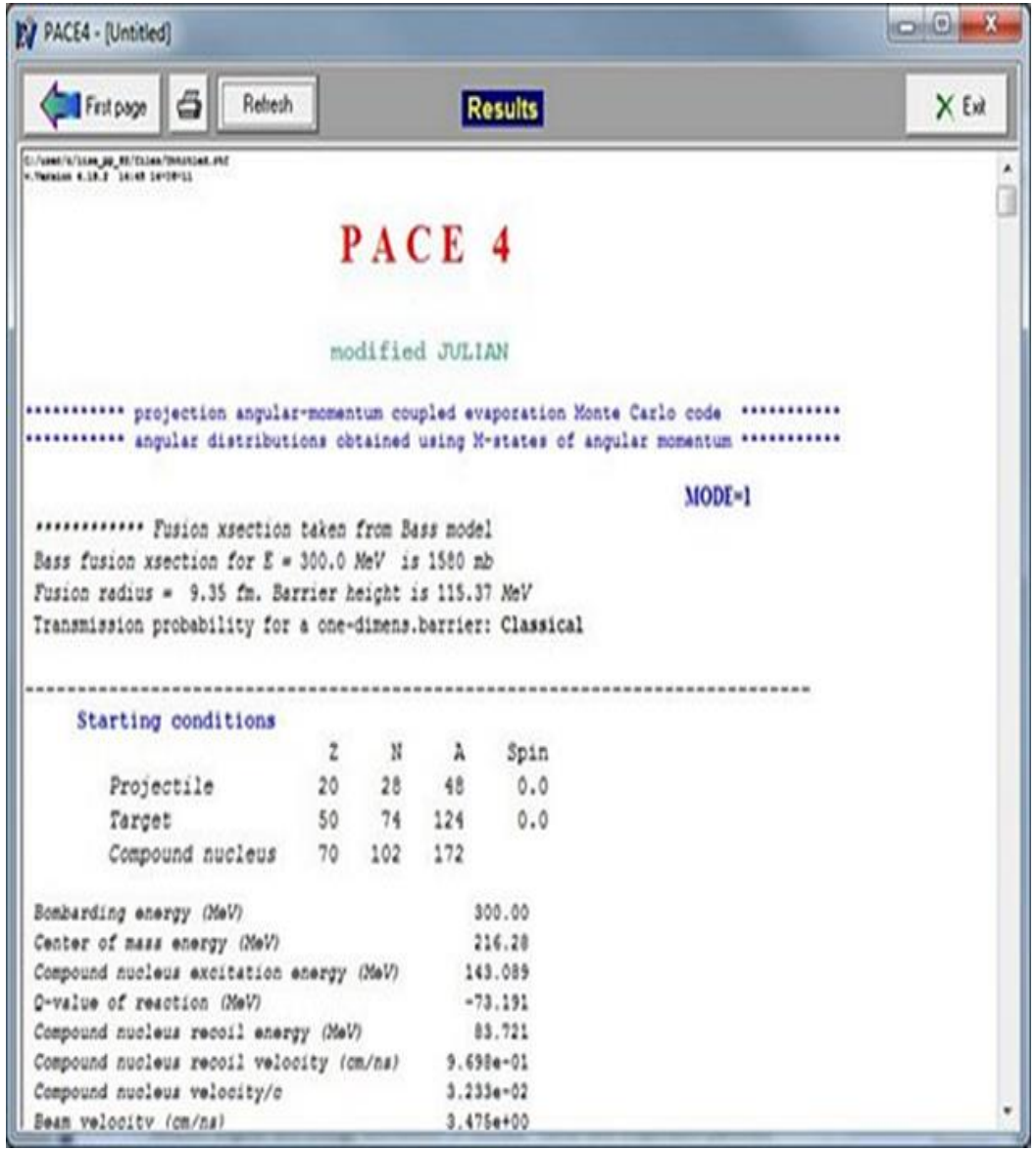


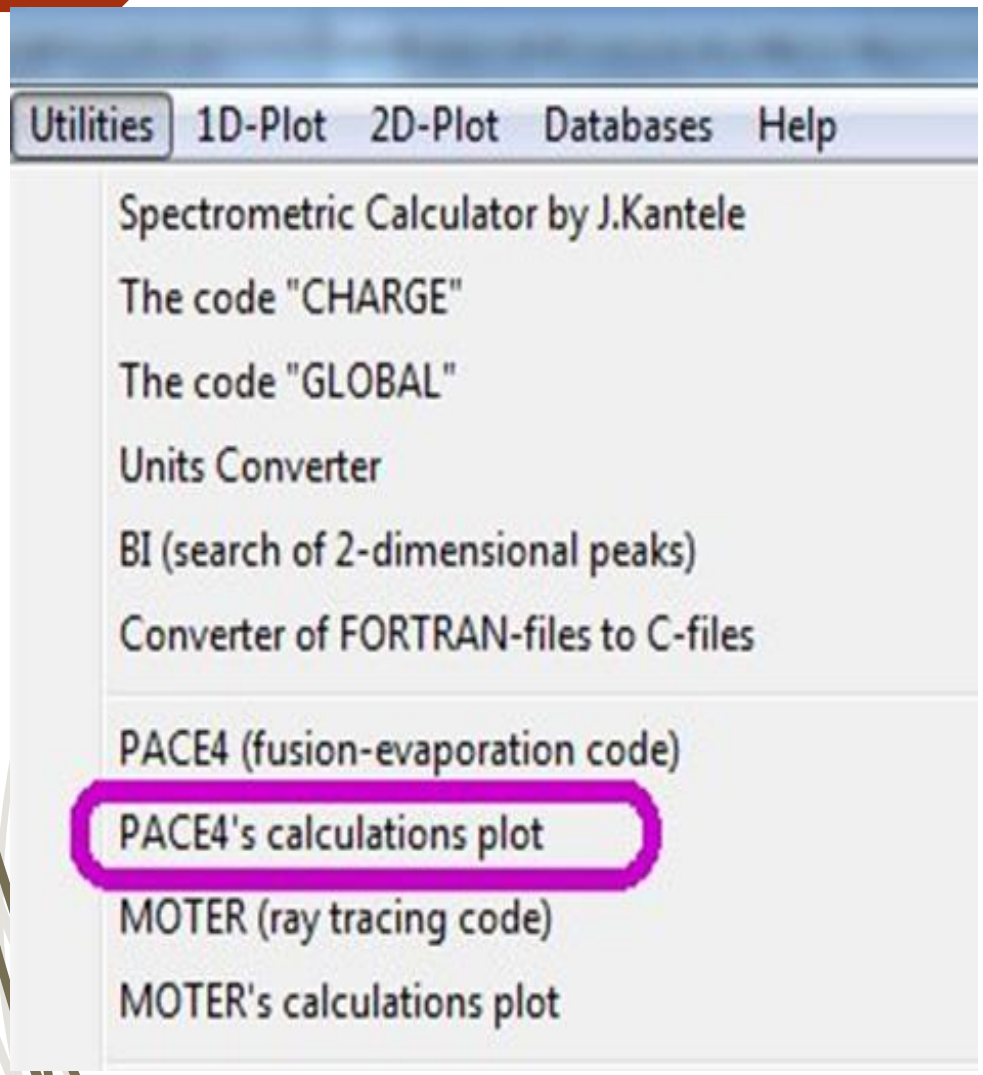


By using nex tab, code start the calculation with other default parameters.

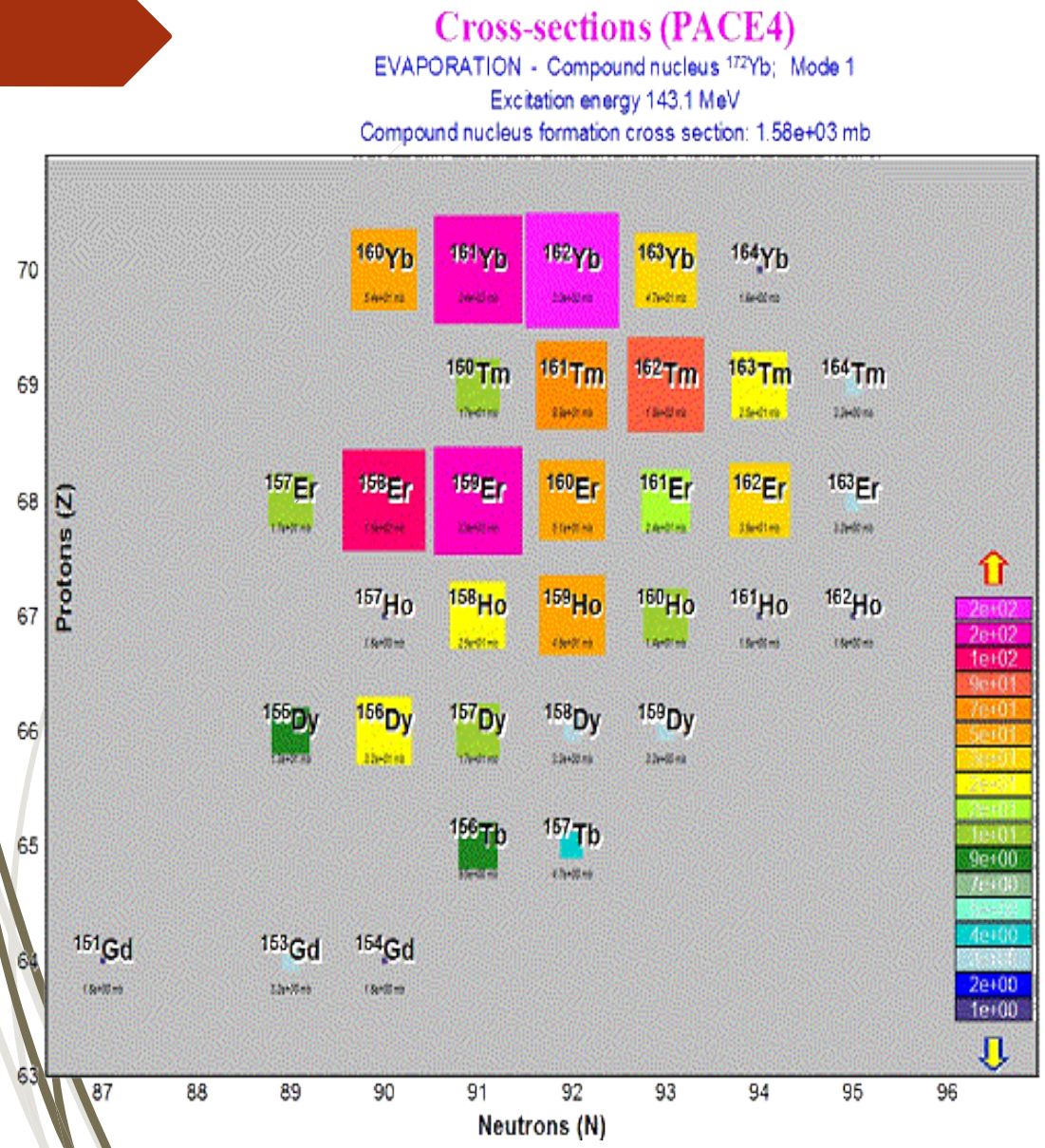
After calculation PACE4 code gives an output file as follows.



PLOTTING PACE4 RESULTS with LISE++



- Under the Utulities tab in the LISE++ program; the desired results can be obtained graphically with the plotting tab of the PACE4 code

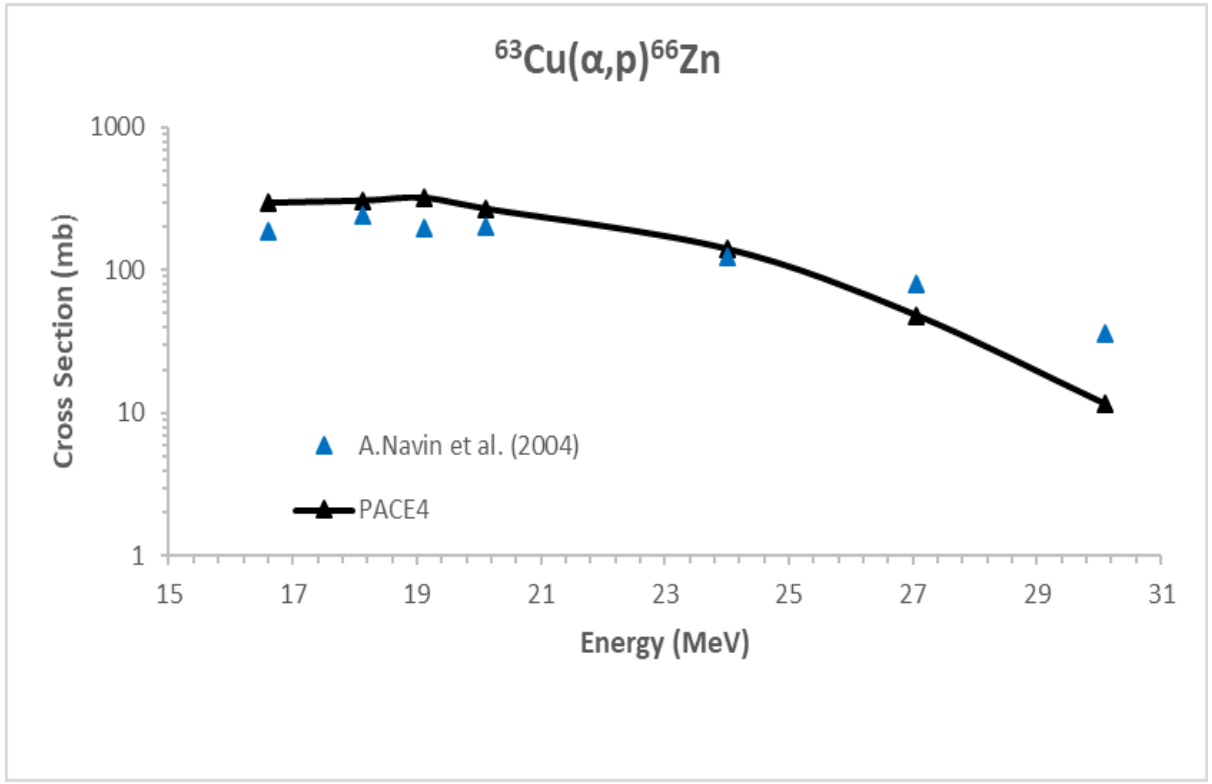


After plotting one can see cross-section values for all residual nuclei in this way.

- If it is interested in only one residual nuclei, an excel worksheet can be created for the cross section values corresponding to different energy values for that nuclei, and as a result, the energy versus effect cross section graph can be drawn.

To give a few examples of the work done with the pace 4 code

- In this experiment reactions induced by radioactive 6,8He beams have been studied on 63,65Cu and they compared to reactions with stable 4He projectiles. All evaporation redisues compared with each other with different beam options.(A.Navin et al)
- Example on the right side only one evaporation residue from this experiment . The results for unstable 6,8He beam was not good agrement with calculations of code PACE4. But with stable 4He beam results was good agrement with code.



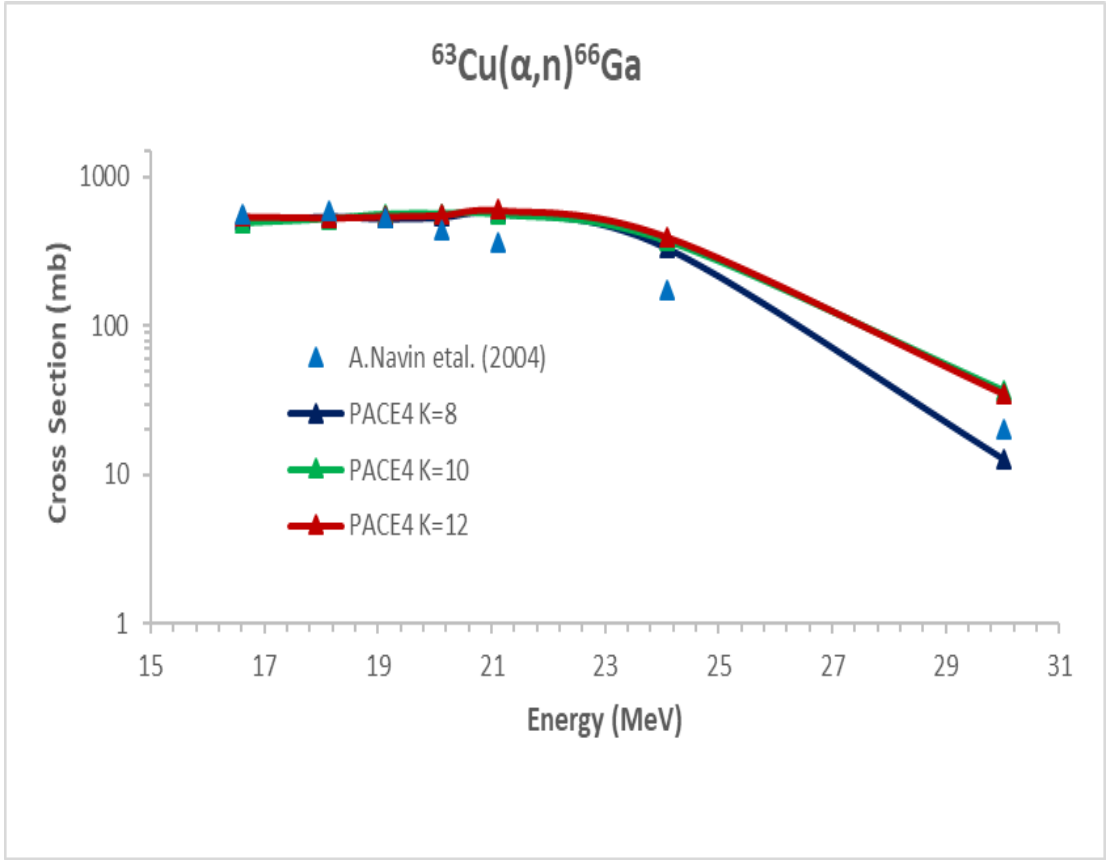
To give a few examples of the work done with the pace 4 code

Code has been modified to take into account the excitation energy dependence of the level density parameter using the prescription Kataria *etal.*

In this code the level density parameter a, which largely affects the equilibrium state components of a cross section is calculated from the expression;

a = A/K MeV−1, where A is the nucleon number of a compound system and K is an adjustable constant, which may be varied to match the experimental data.

The example on the right side ; calculations were done with different level density parameters.



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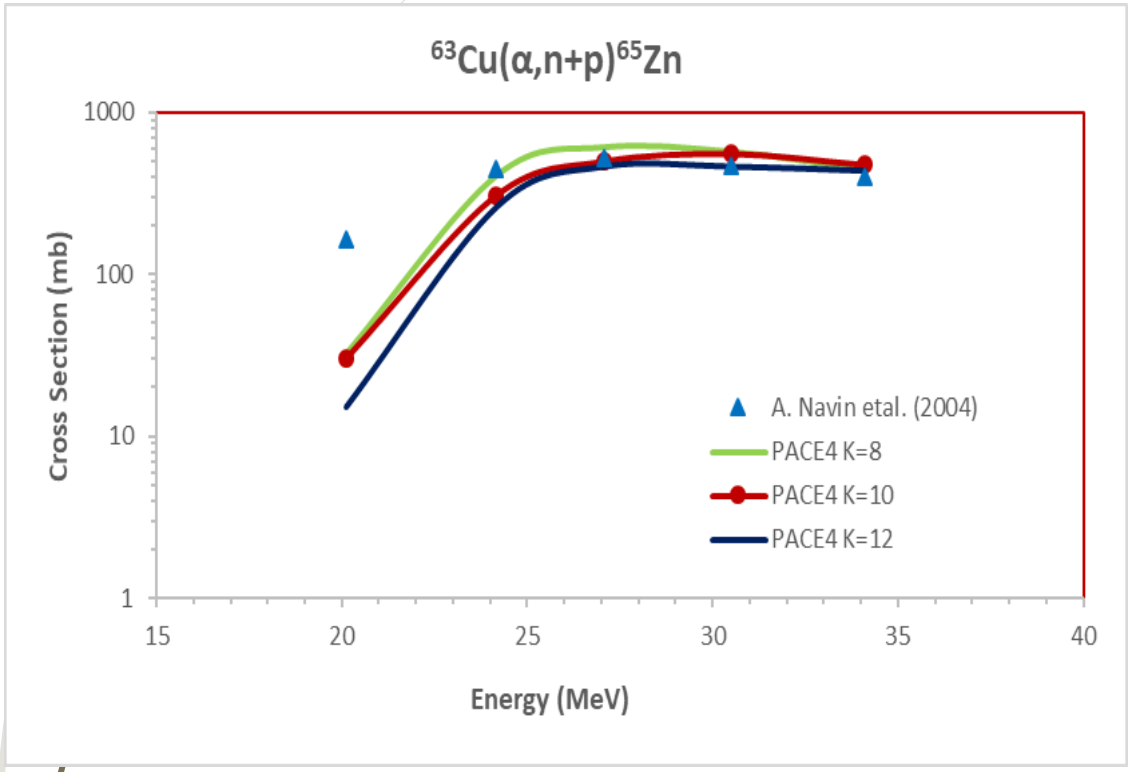
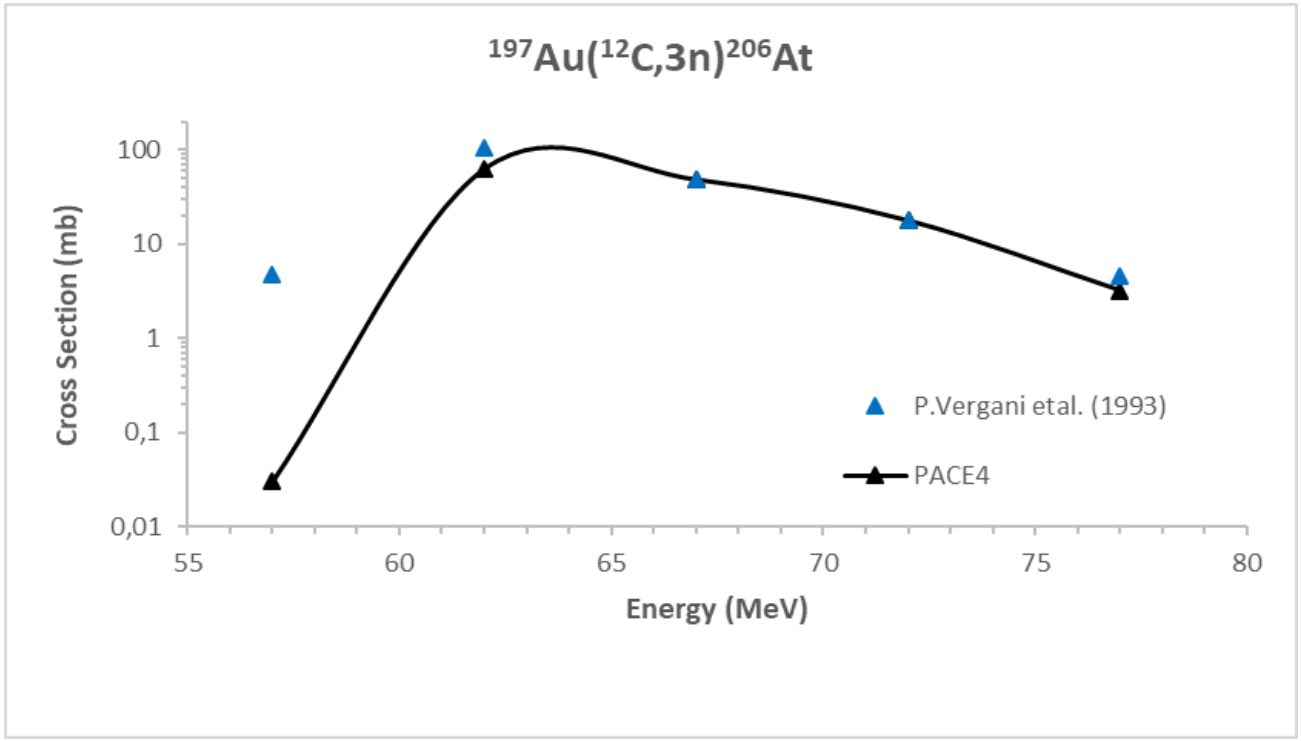


This evaporation residue also from same experiment with different level densitiy parameters.

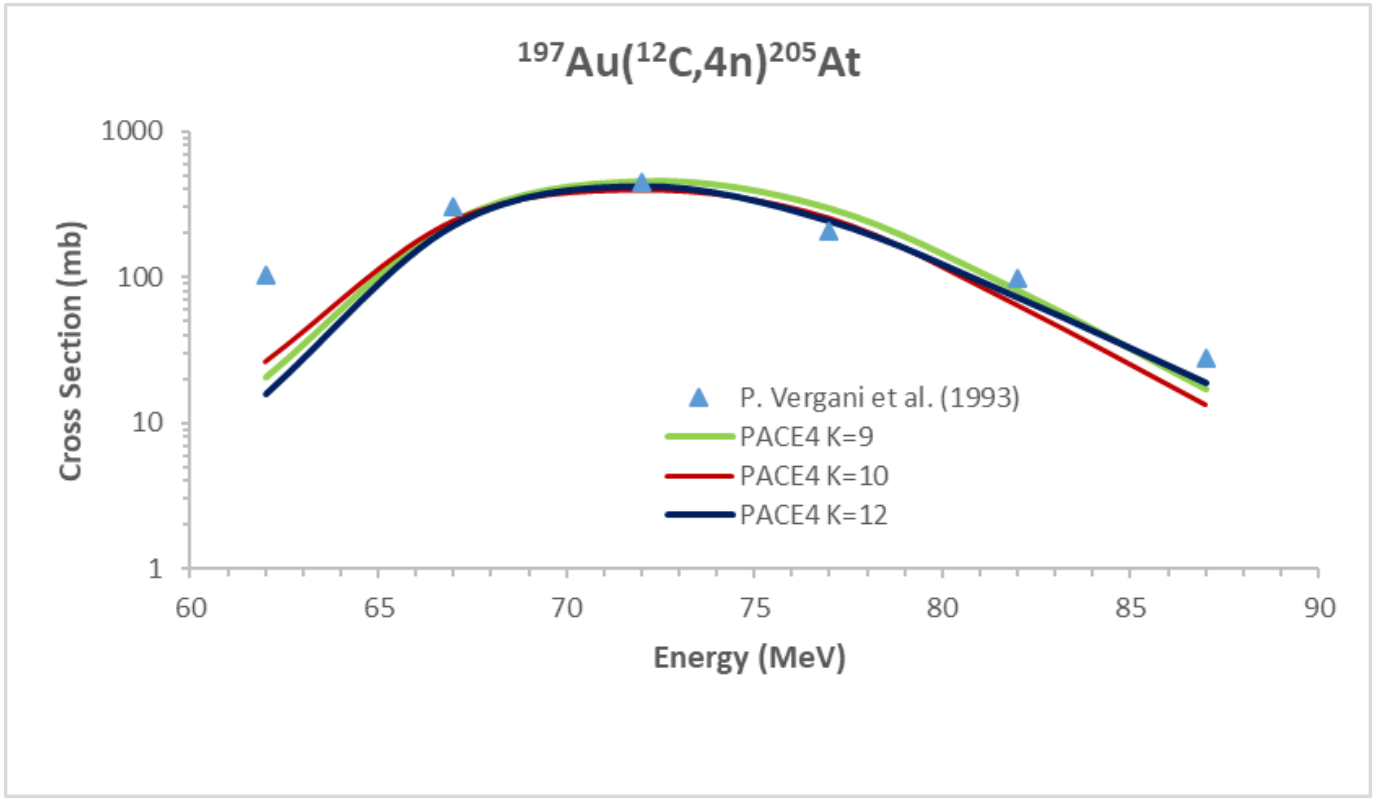
To give a few examples of the work done with the pace 4 code

- On this example; experiment has been done for ''Complete and incomplete fusion and emission of preequilibrium nucleons in the interaction of '12C with 197 Au below 10 MeV/nucleon'' by P.Vergani et al



To give a few examples of the work done with the pace 4 code

- Result for 197Au (12C,4n) 205 At reaction with different level density parameters



REFERENCES

- D. Bazin, M.Lewitowicz, O.Sorlin, O.Tarasov, Nucl. Instr. and Meth. A 482 (2002),314, http://dnr080.jinr.ru/lise and http://www.nscl.msu.edu/lise.
- O. B.Tarasov, D.Bazin, Nucl. Instr. and Meth. B 204 (2003) 174
- Gavron, A. "Statistical model calculations in heavy ion reactions." Physical Review C 21.1(1980): 230.
- O. B. Tarasov, D. Bazina , Nuclear Physics A 746 (2004) 411c–414c, LISE++ : design your own spectrometer
- http://groups.nscl.msu.edu/lise/5 13/lise 5 13.html
- C. Beck et al.,''Near-barrier fusion of weakly bound 6Li and 7Li nuclei with 59Co'' Physical Review C 67, 054602 (2003)
- P. Vergani et al., '' Complete and incomplete fusion and emission of preequilibrium nucleons in the interaction of ' C with ' Au below 1Q MeV/nucleon'' Physical Review C48.4 (1993)
- J.J. Read etal., ''Compound Nucleus Formation Mechanisms in Reaction of Heavy Ions with Medium-Mass Elements'' Physical Review 127.5 (1962)
- S.K. Kataria.et al. (1978), Phys.Rev.C18, 549
- A.Navin et al. ''Direct and compound reactions induced by unstable helium beams near the Coulomb barrier'' Physical Review C 70, 044601 (2004)
- P.Vergani et al. '' Complete and incomplete fusion and emission of preequilibrium nucleons in the interaction of ' C
- with ' Au below 1Q MeV/nucleon'', Physical Review C 48,4 (1993)

Thanks for listening