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"Investing in Sustainable Development"

Extreme Light Infrastructure-Nuclear Physics
(ELI-NP) - Phase II

Photonuclear reactions in astrophysical p-process: Theoretical calculations and experiment simulation based on ELI-NP

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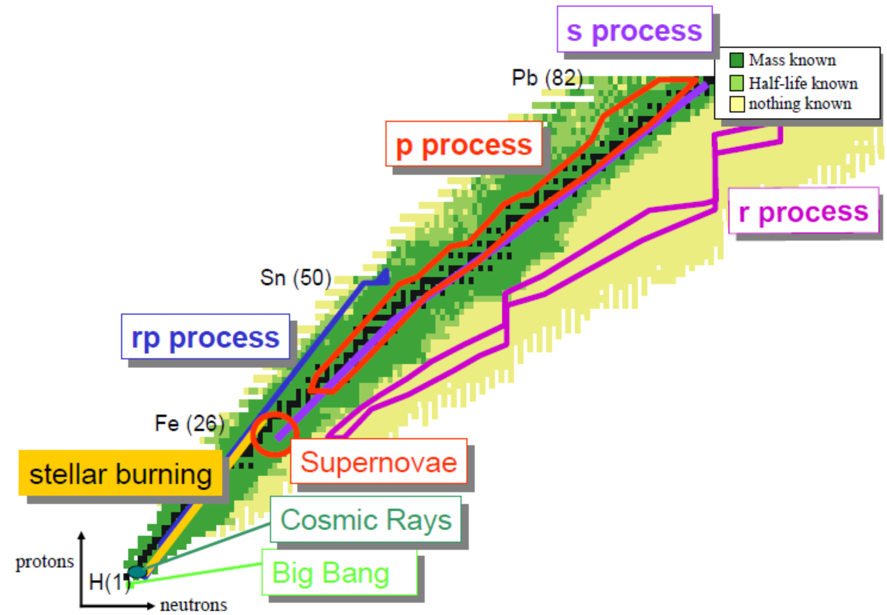
1. Astrophysical background

In general, proton-rich and stable nuclei beyond Fe which can not be synthesized by s- and r- processes are produced by p- process via (γ,n), (γ,p), and (γ,α) reactions.
In particular, the isotopes of molybdenum (Mo) and ruthenium (Ru) observed in our solar system are mainly synthesized by p- process.
P- process includes thousands of photonuclear reactions involving (γ,n), (γ,p), and (γ,α) channels, and the reaction rates for these photonuclear reactions should be determined accurately.

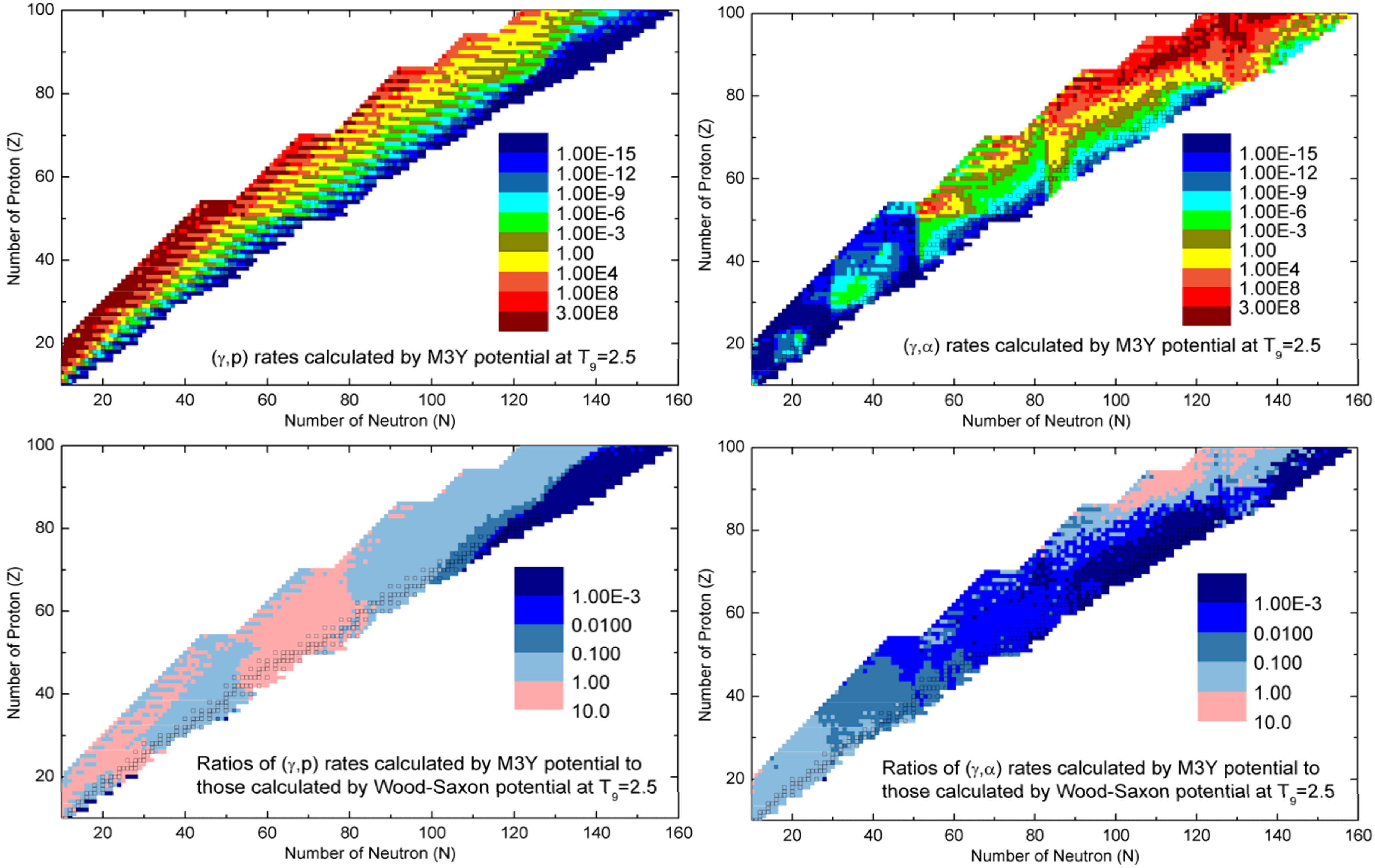


2. Reaction rates calculations with nuclear structure ingredients

Nuclear mass from HFB+Skyrme force, Experimental levels from RIPL-3	→
Microscopic nuclear level density (NLD), QRPA E1 γ-strength function	→
2 kinds of potentials, global Wood-Saxon and M3Y double folding potentials, are used for the calculations.	→
Stellar enhancement factor (SEF) from partition function deduced by NLD ***Ground state contribution is quite small for photon-induced reaction rate!***	→

Calculations of photo-disintegration reaction rates of (**γ**,n), (**γ**,p), and (**γ**,**α**) on about 3000 nuclei are performed based on TALYS with specific nuclear structure ingredients.

3. Calculated reaction rates for (γ,p) and (γ,α) at T_9=2.5

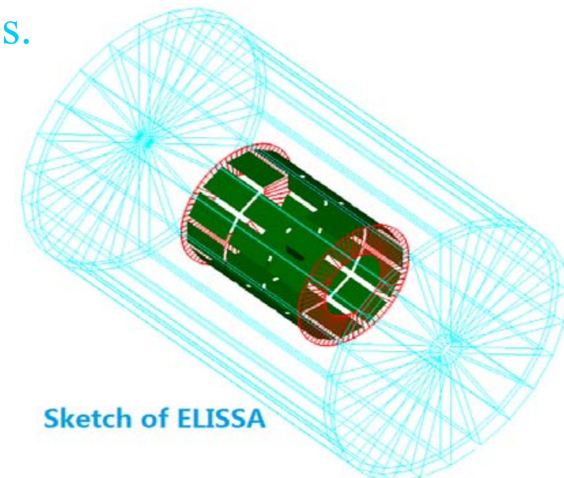


The (γ,α) reaction rates are very sensitive to the nuclear potential. Therefore, the measurements of photonuclear cross sections, especially for (γ,α), are proposed based on the ELI-NP facility. The nuclear potential can extracted by fitting the experimental photonuclear cross section with advanced models.

4. Proposed measurements of (γ,p) and (γ,α) based on ELI-NP and experimental simulations

Intense brilliant γ-beams tunable from 0.2 to 19.5 MeV will be provided by ELI-NP at Magurele, Bucharest in Romania. The construction of the main building of ELI-NP is finished.

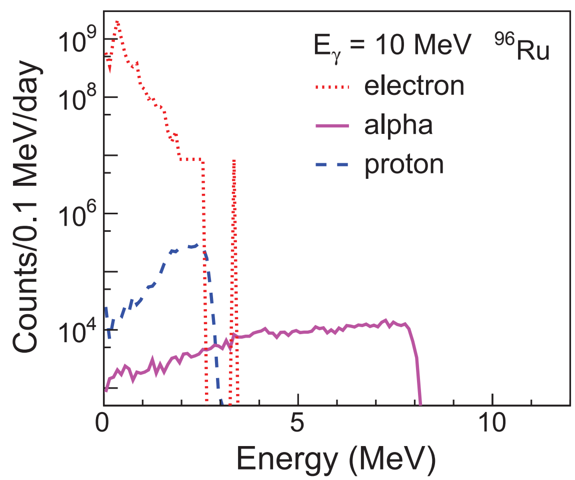
Meanwhile, the ELI-NP silicon-strip detector array (ELISSA), is also being developed for the detections of charged particles.

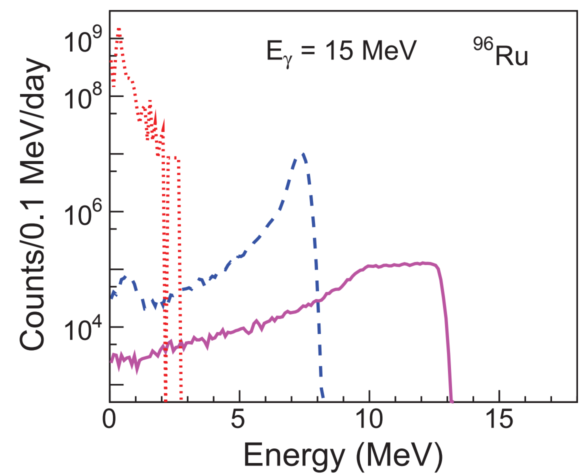


Main characteristics of the gamma beam system at ELI–NP.

Gamma beam parameter	Value
Energy [MeV]	0.2–19.5
Spectral density [ph/s/eV]	$0.8–4 \cdot 10^4$
Bandwidth (bdw) rms [%]	$\leqslant 0.5$
#Photons/s within FWHM bdw	$\leqslant 8.3 \cdot 10^8$
Source rms size [μm]	10–30
Source rms divergence [μrad]	25–200
Pulse length rms [ps]	0.7–1.5
Linear polarization [%]	$\geqslant 99$
Macro repetition rate [Hz]	100
Number of pulses/macropulse	32
Pulse-to-pulse separation [ns]	16
Brilliance at peak energy [1/s mm^2 mrad^2 0.1%bdw]	$10^{20}–10^{23}$
Source position transverse jitter [μm]	<5
Energy jitter pulse-to-pulse [%]	<0.2
Number of photons jitter pulse-to-pulse [%]	$\leqslant 3$

Simulations for $^{96}Ru_{g.s.}$(γ,p) and $^{96}Ru_{g.s.}$(γ,a) experiments are performed with GEANT4, and the counts of α-particle and proton are presented. Features of ELI-NP γ-beams and ELISSA are taken into account. TALYS-based cross sections are used.






Thank you very much!