Letter of Intent for the SPES project

Pre-equilibrium emission: a tool to study dynamic effects and clustering structure in exotic nuclei

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PHYSICS CASES

TO STUDY

1. THE CROSS-SECTIONS OF THE NEUTRON, PROTON AND ALPHA CHANNELS IN THE PRE-EQUILIBRIUM AND EVAPORATIVE EMISSION PROCESSES.

2. THE ALPHA PARTICLE PREFORMATION PROBABILITY IN THE COMPOUND NUCLEUS PROVIDING INFORMATION ON ALPHA-CLUSTER STRUCTURE OF THE NEUTRON-RICH NUCLEI.

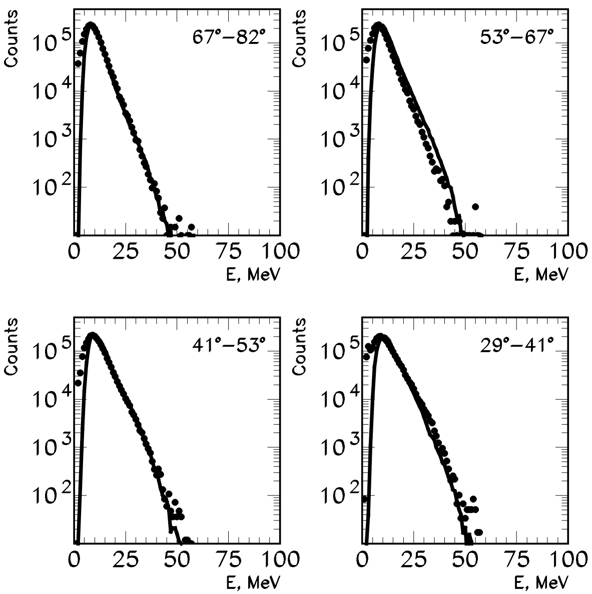
3. ALPHA CLUSTERIZATION AND ITS INFLUENCE ON THE INITIAL EXCITON CONFIGURATION OF THE NON-EQUILIBRIUM PARTICLES IN THE EXOTIC SYSTEMS ON THE INITIAL STAGE OF THE FUSION PROCESS TESTING THE EMPIRICAL CINDRO-BETAK TREND.

4. THE FUNDAMENTAL NUCLEAR PHYSICS QUANTITIES LIKE NUCLEAR TEMPERATURE AND LEVEL DENSITY CONSIDERING THE EVAPORATIVE PART OF THE TOTAL EMISSION SPECTRUM.

LIGHT PARTICLE EMISSION MECHANISMS

V.L. Kravchuk et al, Eur. Phys. Journ. WoC 2(2010)10006
V.L. Kravchuk et al, Int. Journ. Mod. Phys. E *in press* 2010
O.V. Fotina, V.L. Kravchuk et al, Phys. Atom. Nucl. 73(2010)1317
O.V. Fotina, V.L. Kravchuk et al, Int. Journ. Mod. Phys. E 19(2010)1134
A. Corsi, O. Wieland, V.L. Kravchuk et al, Phys. Lett. B 679(2009)197

Evaporative emission

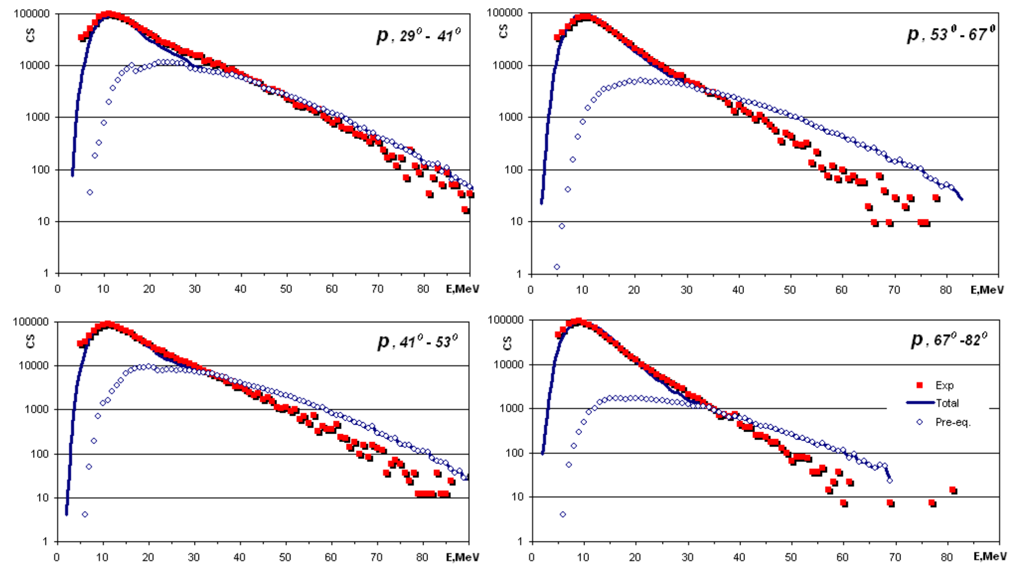


p 8 MeV/u $^{16}O+^{116}Sn$

INFORMATION ON:

- Apparent nuclear temperature
- Level density
- Average kinetic energy

Pre-equilibrium emission



p 15.6 MeV/u $^{16}O+^{116}Sn$

INFORMATION ON:

- Memory of the entrance channel
- Preformation probabilities
- Clusterization in the projectile nucleus

THEORETICAL MODEL

Evaporative (statistical) emission:

The method of analysis of heavy-ion reactions is based on the statistical theory of nuclear reactions using Monte-Carlo simulation of a number of characteristics of nucleus disintegration (modified PACE2 code):

- decay channel (n, p, alpha, gamma or fission);
- kinetic energy of escaping particles;
- particle escaping angels, and (or) angular momentum of emitting particles.

Probabilities of all process were estimated within Hauser-Feshbach model

Pre-equilibrium emission :

- To describe the relaxation processes in the nuclear system produced in the fusion reaction Hybrid exciton model based on Griffin exciton model was used {J.J. Griffin, Phys. Rev. Lett., **478**, p 478 (1966)}.
- In the Hybrid exciton model, the state of the nuclear system produced by collision of bombarding particle and target nucleus is determined by the exciton number ***n = p + h***, where ***p*** is a number of particles located above the Fermi energy and ***h*** is a number of holes located under the Fermi energy, and by excitation energy ***E****. The exciton number can be determined from the empirical trend (N. Cindro et al., Phys. Rev. Lett. 66(1991)868).
- More detailed description of using method can be found in O.V. Fotina, et al. Phys. of Atomic Nuclei, Vol. 73, No 1, 2010, p. 1317 and ref. therein
- We regard as free parameter next values ***n, k, g.***
  - ✓ ***k*** is parameters, connected with transition matrix element $\langle|M|^2\rangle$ and determined of the transition rate of emission particle into continuum with energy ε_b. This parameter was varied in wide region from 200 to 800 MeV^3.
  - ✓ The single particle level density ***g*** is connected with the level density parameter in the Fermi-gas model by relation $g = 6a/\pi^2$. For variation of values ***g*** we used Fermi-gas model and level-density phenomenological model {A.V. Ignatyuk, K.K. Istekov, and G.N. Smirenkin, [Yad. Fiz., **29**, 875 (1979)] Sov. J. Nucl. Phys. **29**, 450, 1979
  - ✓ And ***n*** is mentioned above exciton number. The initial exciton configuration (p_0,h_0) from which the equilibration process starts is the free parameter of the model. In our calculations we used next of the initial exciton configurations: n_0 **= (16p,1h) (** $^{16}O+^{116}Sn$**)**.

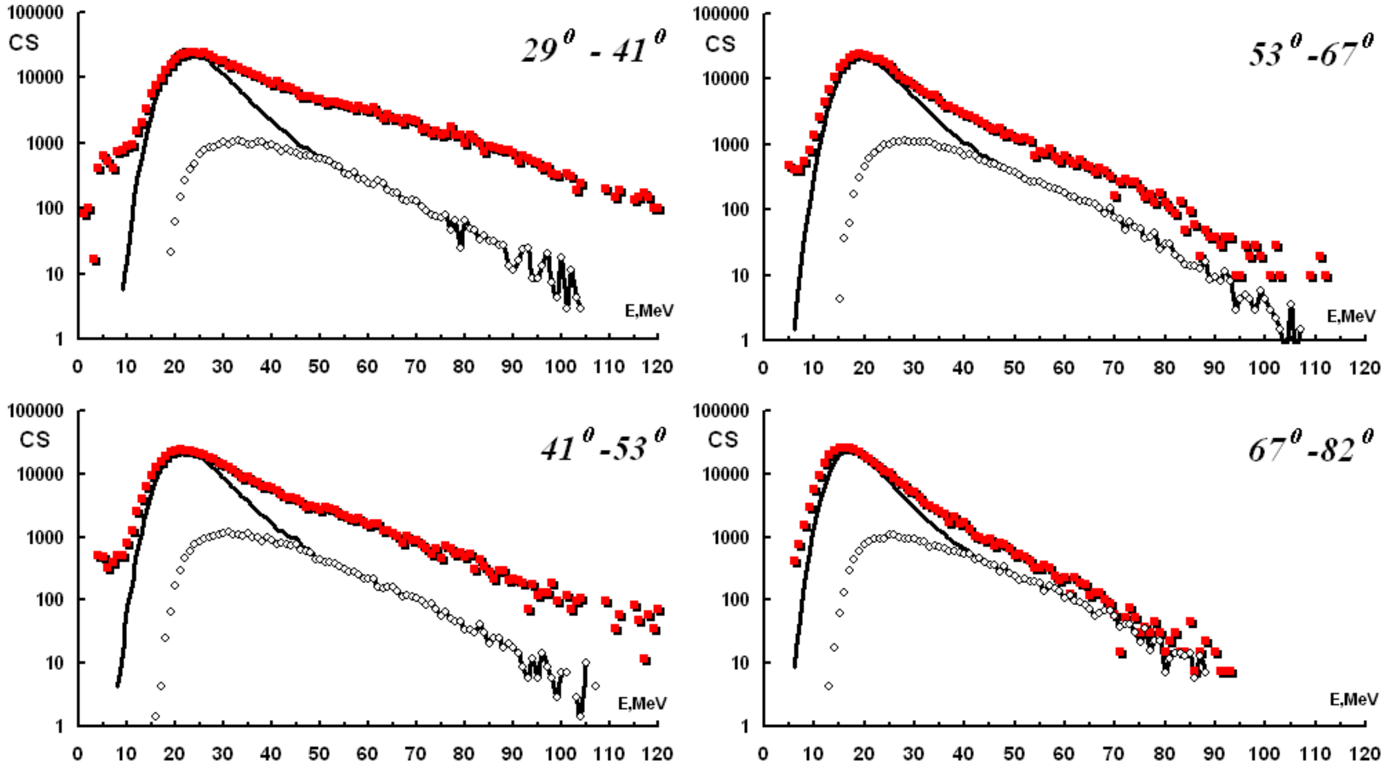
INFLUENCE OF ALPHA CLUSTERIZATION ON THE INITIAL EXCITON CONFIGURATION

Exp. Data + Model calculation

15.6 MeV/u $^{16}O+^{116}Sn$ (16p, 1h configuration)

$E^*/n_0 = 6.8 + 0.54(E_{CM} - V_C)/A_P$ *N. Cindro et al, PRL 66(1991)868*

α **spectra**



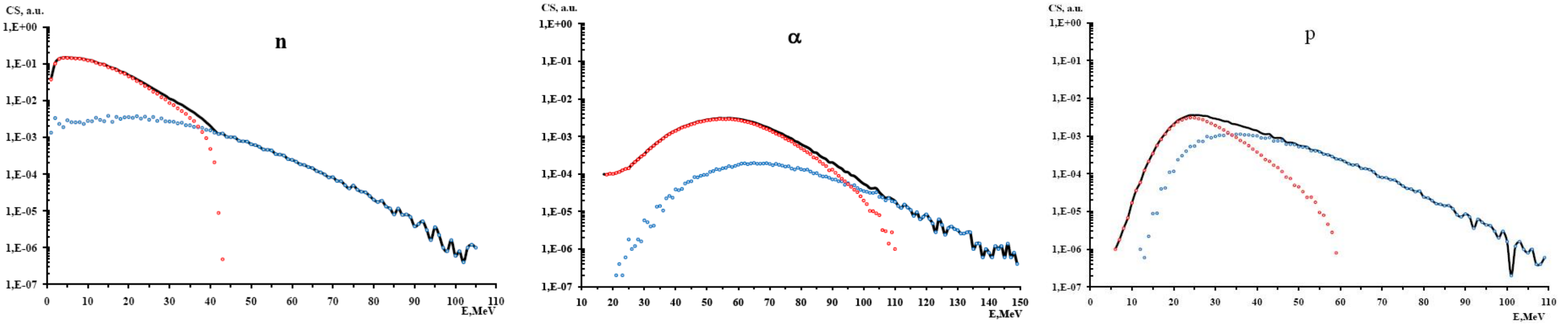
ALPHA PARTICLE PREFORMATION PROBABILITY

Model calculation

11 MeV/u $^{132}Sn+^{27}Al$ (27p, 2h configuration)

Ψ_o	M_n			M_α			M_p		
	Evap	Pre-eq	Total	Evap	Pre-eq	Total	Evap	Pre-eq	Total
0.00	**11.70**	**0.805**	**12.51**	**0.525**	**0.031**	**0.556**	**0.316**	**0.164**	**0.480**
0.12	**11.76**	**0.729**	**12.49**	**0.515**	**0.044**	**0.559**	**0.303**	**0.226**	**0.529**

Ψo = 0.12



ON THE REACTION CHOICE

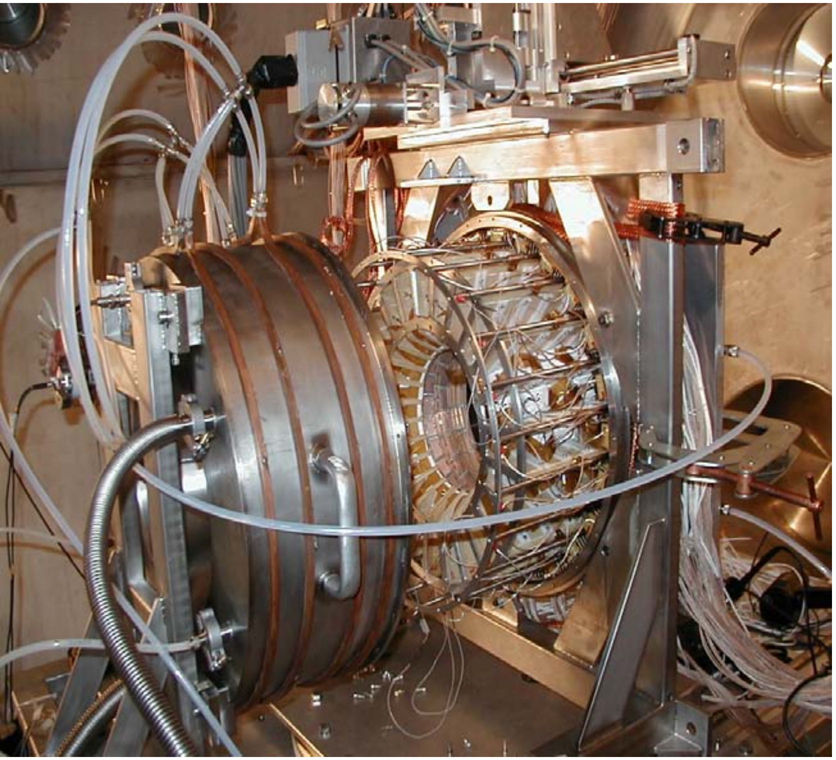
11 MeV/u $^{132}Sn+^{27}Al$

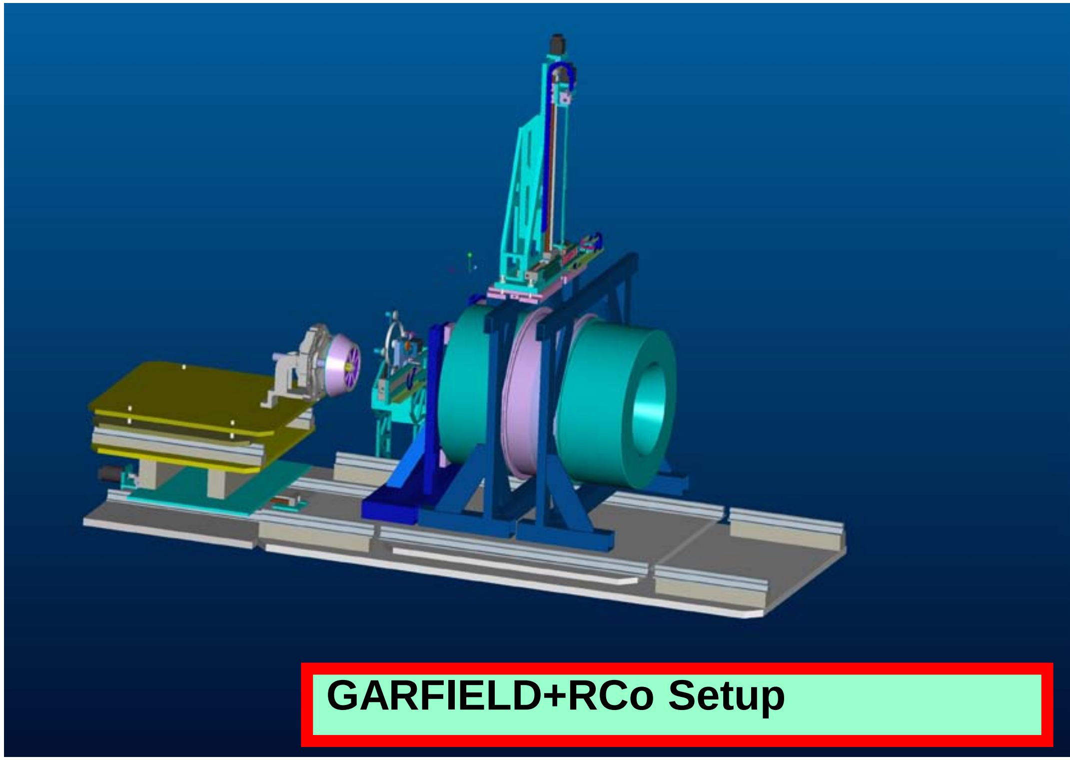
- ^{132}Sn beam: SPES intensity
  $3.11 \cdot 10^{7}$ particles/s
- alpha pre-equilibrium cross section ($\psi_0 = 0.00$)
  $\sigma_{PE\alpha} = 38$ mbarn
- alpha particle preformation probability from analytic expression (H.F. Zhang et al, PRC 80(2009)057301)
  $\psi_0 = 0.12$

- ...FEASIBLE...

GARFIELD

General **AR**ray for **F**ragment **I**dentification and **E**mitted **L**ight particles in **D**issipative collisions





- High granularity (~400 ΔE-E telescopes $\vartheta \approx 4^o$-150^o)
- Low energy thresholds (ionization chambers as ΔE)
- Z identification: $\vartheta \approx 4^o$-150^o
- A and Z identification: (1<=Z<=12) $\vartheta \approx 4^o - 20^o$ (Si-CsI digital pulse shape)
  (Z=1-3) $\vartheta \approx 30^o - 150^o$ (CsI digital pulse-shape)

RipeN

Rivelatori per Neutroni a LNL

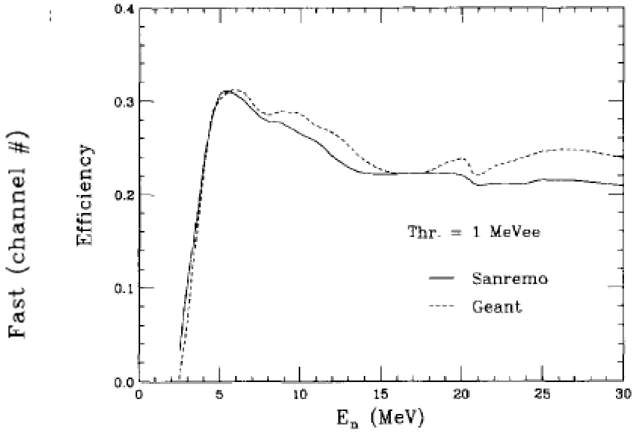
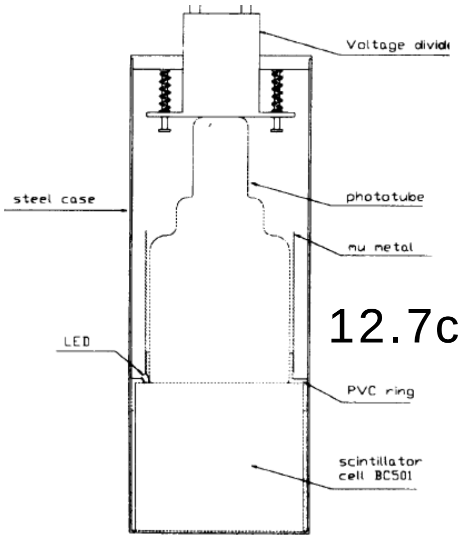


Fig. 8. Simulated efficiency of the detector as a function of the neutron energy for 1 MeV ee threshold on the light output. The solid and dashed curves are the results of SANREMO and Geant-based codes respectively.



12.7cm x 12.7 cm

24 BC501 cylindrical Liquid Scintillators