FUNDING APLICATION FOR
EXPLORATORY RESEARCH PROJECTS - PN-II-ID-PCE-2011-3
Section 3

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B. Project leader DELION DORU-SABIN

B1. Scientific visibility and prestige (maximum 2 pages)

B.1.1. *Main research results.*

The main recognized research results in several fields of the theoretical nuclear physics, connected to the topics of this project, namely: **many-body methods, proton emission, α-clustering and decay, heavy cluster decays, and cold fission,** are shortly described below.

1) Derivation of the effective pairing interaction in spherical nuclei within the G-matrix approach, starting from the realistic Paris two-body interaction. An analytic separable solution for spherical nuclei was obtained. It is recognized by several review papers as an important contribution in computing the effective pairing potential starting from a realistic interaction.
-*D.S. Delion*, M. Baldo, U. Lombardo, *Finite size effects in the gap equation for Paris interaction*, Nuclear Physics A **593**, 151-161 (1995).

2) Self-consistent microscopic description of the angular distribution and absolute value of the decay width in cluster emission processes, by using a new very efficient single particle basis with two harmonic oscillator parameters. The first part of the basis describes spectroscopic properties, while the second part is connected to clustering features. The review paper on cluster decays published in Physics Reports **294**, 265-362 (1998) obtained 98 citations. The papers on microscopic description of the anisotropy and decay width are mentioned as important contributions in this field, collecting more than 100 citations.
- *D.S. Delion*, A. Insolia, R.J. Liotta, *Anisotropy in alpha decay of odd-mass deformed nuclei*, Physical Review C **46**, 884-888 (1992); *Alpha widths in deformed nuclei: Microscopic approach,* Physical Review C **46**, 1346-1354 (1992); *New single particle basis for microscopic description of decay processes*, Physical Review C **54**, 292-301 (1996).
- *D.S. Delion*, A. Sandulescu, W. Greiner, *Evidence for alpha-clustering in heavy and superheavy nuclei,* Physical Review C **69**, 044318/1-19 (2004).

3) The systematics of the α-decay fine structure and double fine structure in cold fission, by using the coupled channel approach in describing the dynamics and double folding procedure to determine the interaction potential. The paper on α-decay fine structure was mentioned by almost all papers on α-decay, collecting up to now 25 citations in 5 years.
- *D.S. Delion*, S. Peltonen, J. Suhonen, *Systematics of the alpha decay to rotational states,* Physical Review **C73**, 014315/1-10 (2006).

- *D.S. Delion*, A. Sandulescu, S. Misicu, F. Carstoiu, W. Greiner, *Double fine structure in the binary cold fission,* Journal of Physics G **28**, 289-306 (2002).

4) The first systematics of reduced half lives for proton emitters versus the Coulomb parameter, by excluding the centrifugal barrier. It is mentioned as a leading contribution in the field of proton emission. This paper, together with the review paper on proton emission in Physics Reports, was mentioned practically by all papers in this field, both collecting 33 citations in 5 years.
- *D.S. Delion*, R.J. Liotta, R. Wyss, *Systematics of proton emission*, Physical Review Letters **96**, 072501/1-4 (2006); *Theories of proton emission*, Physics Reports **424**, 113-174 (2006).

5) Analytic derivation of a universal law expressing the logarithm of the reduced decay width of proton, alpha and heavy cluster emission processes in terms of the fragmentation potential. This law explains in particular the existence of the two straight lines, fitting the above mentioned systematics of proton emitters. The paper collected 10 citations during the last year.
- *D.S. Delion, Universal decay rule for reduced widths*, Physical Review C **80**, 024310/1-7 (2009).

B.1.2. *The visibility of the scientific contributions.*

Invited talks were given at several institutes and universities where I was invited:
1) Physics Department - Catania University, Italy, 1990-1995 (3 months/year)
1) Royal Institute of Technology, Stockholm, Sweden, 1996 (6 months), 1997-2010 (2 month/year)
2) Institut de Sciences Nucléaire, Grenoble, France, 1996, 1998 (3 months/year)
3) Institut de Physique Nucléaire, Orsay, France, 1998-2010 (1 month/year)
4) Physics Department - Jyväskylä University, Finland, 1997-2009 (1 month/year)
5) Physics Department - Frankfurt University, Germany, 2001-2003 (2 months/year)

Invited talks at international conferences are given below in Section B.2. Curriculum Vitae/ "3. Selected list of papers published in Proceedings of int. conferences as a principal author"

Member of the Editorial board of:
Digest Journal of Nanomaterials and Biostructures (ISI=1.75)
http://www.chalcogen.infim.ro/digest.html

Scientific referee in the field of emission processes and fission at the following journals:
1) Physical Review **C** (ISI=3.47)
2) Journal of Physics **G** (ISI=2.12)
3) European Physical Journal **A** (ISI=2.01)
4) Nuclear Physics **A** (ISI=2.10)
5) Physics Letters **B** (ISI=3.06)

***B2. Curriculum vitae** (max. 4 pages)*

DELION DORU-SABIN http://www.theory.nipne.ro/~delion

a) Education: Faculty of Physics -Theoretical Physics, Univ. of Sankt-Petersbourg, Russia, 1976

Degree: Ph.D. in Physics, Institute of Atomic Physics, Bucharest, 1989 , Thesis:

"Description of M1 and M3 magnetic states in even-even nuclei and M1 states in odd nuclei"

b) Professional experience:

1) Central Institute of Physics, Bucharest, Laboratory of numerical analysis, Researcher, 1979-1990

2) "Horia Hulubei" Institute of Physics and Nuclear Engineering, Theoretical Physics Department, Researcher: 1990-1995, Senior researcher: 1995-present

3) Physics Department, University of Bucharest, Associated professor, 2000-present

4) Director of scientific projects: CERES 1-64/2001, CERES 4-162/2004, IDEI 119/2007

c) List of publications and citations, containing:

80 papers in foreign ISI journals, 3 papers in other foreign journals, 28 papers in journals of the Romanian Academy, 19 papers in Proceedings of international conferences, 3 books, 1 chapter,

is given at the address: http://www.nipne.ro/research/publications/publications.php?user=51

d) Hirsch index = 16, Total number of ISI citations = 880

e) Address of the resercherid.com profile: http://www.researcherid.com/rid/B-9609-2011

1. Synthetic list of papers published in foreign ISI journals

1.1. *D.S. Delion*, K.A. Gridnev, E.F. Hefter, V.M. Semionov, J. Phys. G **4**, 125-132 (1978)

1.2. *D.S. Delion*, K.A. Gridnev, E.F. Hefter, V.M. Semionov, Z. Phys. A **297**, 115-121 (1980)

1.3. A.A. Raduta, I.I. Ursu, *D.S. Delion*, Nucl. Phys. A **475**, 439-467 (1987)

1.4. A.A. Raduta, *D.S. Delion*, Nucl. Phys. A **491**, 24-44 (1989)

1.5. A.A. Raduta, *D.S. Delion*, Nucl. Phys. A **513**, 11-28 (1990)

1.6. A.A. Raduta, *D.S. Delion*, I.I. Ursu, N. Lo Iudice, Phys. Rev. C **44**, 1929-1943 (1991)

1.7. A. Insolia, P. Curuchet, R.J. Liotta, *D.S. Delion*, Phys. Rev. C **44**, 545-547 (1991)

1.8. D. Mihalache, D. Mazilu, *D.S. Delion*, Phys. Rev. A **46**, 4449-4452 (1992)

1.9. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. C **46**, 1346-1354 (1992)

1.10. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. C **46**, 884-888 (1992)

1.11. *D.S. Delion*, A. Insolia, R.J. Liotta, Nucl. Phys. A **549**, 407-419 (1992)

1.12. N. Lo Iudice, A.A. Raduta, *D.S. Delion*, Phys. Lett. B **300**, 195-198 (1993)

1.13. A.A. Raduta, *D.S. Delion*, N. Lo Iudice, Nucl. Phys. A **551**, 93-108 (1993)

1.14. *D.S. Delion*, A. Insolia, R.J. Liotta, J. Phys. G **19**, L189-L192 (1993)

1.15. A.A. Raduta, *D.S. Delion*, A. Faessler, Phys. Lett. B **312**, 13-17 (1993)

1.16. A.A. Raduta, A. Faessler, *D.S. Delion*, Nucl. Phys. A **564**, 185-203 (1993)

1.17. *D.S. Delion*, A. Insolia, R.J. Liotta, J. Phys. G **20**, 1483-1498 (1994)

1.18. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. C **49**, 3024-3028 (1994)

1.19. N. Lo Iudice, A.A. Raduta, *D.S. Delion*, Phys. Rev. C **50**, 127-137 (1994)

1.20. A.A. Raduta, V. Baran, *D.S. Delion,* Nucl. Phys. A **588**, 431-462 (1995)

1.21. *D.S. Delion*, A. Florescu, M. Huise, et.al., Phys. Rev. Lett. **74**, 3939-3942 (1995)

1.22. A.A. Raduta, *D.S. Delion*, A. Faessler, Phys. Rev. C **51**, 3008-3016 (1995)

1.23. *D.S. Delion*, M. Baldo, U. Lombardo, Nucl. Phys. A **593**, 151-161 (1995)

1.24. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. C **54**, 292-301 (1996)

1.25. *D.S. Delion*, A. Florescu, M. Huise, et.al., Phys. Rev. C **54**, 1169-1176 (1996)

1.26. A.A. Raduta, V. Baran, *D.S. Delion*, Phys. Rev. E **54**, 3264-3273 (1996)

1.27. A.A. Raduta, *D.S. Delion*, A. Faessler, Nucl. Phys. A **617**, 176-194 (1997)

1.28. *D.S. Delion*, J. Dukelsky, P. Schuck, Phys. Rev. C **55**, 2340-2344 (1997)

1.29. *D.S. Delion*, D. Santos, P. Schuck, Phys. Lett. B **398**, 1-5 (1997)

1.30. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. Lett. **78**, 4549-4552 (1997)

1.31. D.S. Delion, R.J. Liotta, Phys. Rev. C **56**, 1782-1787 (1997)

1.32. R.G. Lovas, R.J. Liotta, A. Insolia, K. Varga, *D.S. Delion*, Phys. Rep. **294**, 265-362 (1998)

1.33. *D.S. Delion*, R.J. Liotta, N. Sandulescu, T. Vertse, Phys. Rev. C **57**, 986-989 (1998)

1.34. F. Krmpotic, E.J.V. Passos, *D.S. Delion*, et.al., Nucl. Phys. A **637**, 295-324 (1998)

1.35. *D.S. Delion*, R.J. Liotta, Phys. Rev. C **58**, 2073-2080 (1998)

1.36. *D.S. Delion*, A. Insolia, R.J. Liotta, Nucl. Phys. A **654**, 673-677 (1999)

1.37. *D.S. Delion*, J. Suhonen, Phys. Rev. C **61**, 024304/1-12 (2000)

1.38. A. Florescu, A. Sandulescu, *D.S. Delion*, et.al, Phys. Rev. **C61**, 051602(R)/1-4 (2000)

1.39. *D.S. Delion,* J. Dukelsky, P. Schuck**,** et.al., Phys. Rev. C **62**, 044311/1-15 (2000)

1.40. *D.S. Delion*, A. Florescu, A. Sandulescu, Phys. Rev. C **63**, 044312 (2001)

1.41. *D.S. Delion*, J. Suhonen, Phys. Rev. C **64**, 061306(R)/1-5 (2001)

1.42. *D.S. Delion*, A. Sandulescu, S. Misicu, et.al., Phys. Rev. C **64**, 041303(R)/1-5 (2001)

1.43. *D.S. Delion*, J. Suhonen, Phys. Rev. C **64**, 064302/1-6 (2001)

1.44. *D.S. Delion*, A. Sandulescu, S. Misicu, F. Carstoiu, W. Greiner, J. Phys. G **28**, 289-306 (2002)

1.45. *D.S. Delion*, A. Sandulescu, J. Phys. G **28**, 617-625 (2002)

1.46. *D.S. Delion*, A. Sandulescu, W. Greiner, J. Phys. G **28**, 2921-2938 (2002)

1.47. *D.S. Delion*, J. Suhonen, Phys. Atomic Nuclei **65,** 621-627 (2002)

1.48. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Atomic Nuclei **65**, 653-657 (2002)

1.49. *D.S. Delion*, A. Sandulescu, W. Greiner, J. Phys. G **29,** 317-336 (2003)

1.50. *D.S. Delion*, A. Insolia, R.J. Liotta, Phys. Rev. C **67**, 054317/1-6 (2003)

1.51. *D.S. Delion*, J. Suhonen, Phys. Rev. C **67**, 034301/1-12 (2003)

1.52. J. Kotila, J. Suhonenn, *D.S. Delion*, Phys. Rev. C **68**, 014307/1-7 (2003)

1.53. *D.S. Delion*, A. Sandulescu, W. Greiner, Phys. Rev. C **68**, 041303(R)/1-5 (2003)

1.54. *D.S. Delion*, R.J. Liotta, R. Wyss, Phys. Rev. C **68**, 054603/1-4 (2003)

1.55. J. Kotila, J. Suhonenn, *D.S. Delion*, Phys. Rev. C **68**, 054322/1-9 (2003)

1.56. *D.S. Delion*, A. Sandulescu, W. Greiner, Acta Phys. Hung. **18,** 403 (2003)

1.57. *D.S. Delion*, A. Sandulescu, W. Greiner, Phys. Rev. C **69**, 044318/1-19 (2004)

1.58. *D.S. Delion*, R. Wyss, D. Karlgren, R.J. Liotta, Phys. Rev. C **70**, 061301(R)/1-5 (2004)

1.59. S. Peltonen, *D.S. Delion*, J. Suhonen, Phys. Rev. C **71**, 044315/1-9 (2005)

1.60. *D.S. Delion*, P.Schuck, J. Dukelsky, Phys. Rev. C **72**, 064305/1-18 (2005)

1.61. J. Kotila, J. Suhonen, *D.S. Delion*, Nucl. Phys. A **765**, 354-369 (2006)

1.62. *D.S. Delion*, R.J. Liotta, R. Wyss, Phys. Rep. **424**, 113-174 (2006)

1.63. *D.S. Delion*, S. Peltonen, J. Suhonen, Phys. Rev. C **73**, 014315/1-10 (2006)

1.64. *D.S. Delion*, R.J. Liotta, R. Wyss, Phys. Rev. Lett. **96**, 072501/1-4 (2006)

1.65. J. Kotila, J. Suhonen, *D.S. Delion*, Czech. J. Phys. **56,** 473-480 (2006)

1.66. *D.S. Delion*, J. Suhonen, Nucl. Phys. A **781,** 88-103 (2007)

1.67. S. Peltonen, *D.S. Delion*, J. Suhonen, Phys. Rev. C **75**, 054301/1-9 (2007)

1.68. *D.S. Delion*, R.J. Liotta, R. Wyss, Phys. Rev. C **76**, 044301/1-8 (2007)

1.69. S. Peltonen, *D.S. Delion,* J. Suhonen, Phys. Rev. C **78,** 034608/1-7 (2008)

1.70. *D.S. Delion,* Int. J. Mod. Phys. E **17,** 2283-2289 (2008)

1.71. J. Kotila, J. Suhonen, *D.S. Delion,* J. Phys. G **36,** 045106/1-13 (2009)

1.72. M. Mirea, *D.S. Delion,* A. Sandulescu, Europhys. Lett. **85** (2009) 12001/1-5

1.73. *D.S. Delion,* Phys. Rev. C **80**, 024310/1-7 (2009)

1.74. J. Kotila, J. Suhonen, *D.S. Delion,* J. Phys. G **37,** 015101/1-12 (2010)

1.75. A. Astier, P. Petkov, M.-G. Porquet, *D.S. Delion*, et.al., Phys.Rev.Lett.**104**,042701/1-4 (2010)

1.76. M. Mirea, *D.S. Delion,* A. Sandulescu, Phys. Rev. C **81,** 044317/1-4 (2010)

1.77. A. Astier, P. Petkov, M.-G. Porquet, *D.S. Delion*, et.al., Mod. Phys. Lett. A **25**, 21-23 (2010)

1.78. *D.S. Delion*, R. Wyss, R.J. Liotta, Bo Cederwall, et.al., Phys. Rev. C **82,** 024307/1-8 (2010)

1.79. *D.S. Delion* and N.V. Zamfir, Phys. Rev. C **82**, 031302/1-4 (2010)

1.80. A. Astier, P. Petkov, M.-G. Porquet, *D.S. Delion*, at.al., Eur. Phys. J. A **46**, 165-185 (2010)

2. Books and Chapters in books published by prestigious Publishing houses

2.1. A.A. Raduta, *D.S. Delion*, I.I. Ursu (editors), *"New Trends in Theoretical and Experimental Nuclear Physics"*, World Scientific, Singapore (1992)

2.2. A.A. Raduta, *D.S. Delion*, I.I. Ursu (editors), *"Collective Motion and Nuclear Dynamics"*, World Scientific, Singapore (1996)

2.3. *D.S. Delion*, A. Insolia and R.J. Liotta, The role of pairing correlations in cluster decay, p265 *"Pair Correlations in Many Fermion Systems"*, Ed. V. Kresin, Plenum Press, New York (1998)

2.4. *D.S. Delion*, *"Theory of particle and cluster emission"*, Springer-Verlag, Berlin (2010)

3. Selected list of papers published in Proceedings of international conferences as a principal author

3.1. *D.S. Delion*, A. Insolia, R.J. Liotta, "Collective Motion and Nuclear Dynamics", Predeal, 1995, Eds. A.A. Raduta, *D.S. Delion*, I.I. Ursu, World Scientific, Singapore (1996) p.313-322

3**.2.** *D.S. Delion*, A. Florescu, A. Insolia, R.J. Liotta, "Fussion and Properties of Neutron Rich Nuclei", Sanibel Island Florida, 1997, World Scientific, Singapore (1998) p.634-636

3.3. *D. S. Delion*, A. Sandulescu, et.al, "Symposium on Nuclear Clusters: from Light Exotic to Super heavy Nuclei", Rauischholzhausen, Germany, 2002, World Scientific, Singapore **(**2003)

3.4. *D. S. Delion*, A. Sandulescu, at.al., "Int. Conf. on Modern Sub-Nuclear and laboratory Experiment', University of Athens, Georgia, USA, 2002, World Scientific, Singapore (2003)

3.5. *D. S. Delion*, A. Sandulescu, et.al., "Third International Conference on Fission and Neutron rich Nuclei", Sanibel Island, Florida, 2002, World Scientific, Singapore (2003)

3.6. *D. S. Delion*, Insolia, R.J. Liotta, "Exotic Clustering", Catania 2002, Eds. S. Costa, A. Insolia, C. Tuve, American Institute of Physics, New York (2002) p.12-19

3.7. *D.S. Delion*, A. Sandulescu, et.al., "New Applications of Nucl. Fission", Bucharest, Romania, 2003, Eds. A.C. Mueller, M. Mirea, L. Tassan-Got, World Scientific, Singapore (2004), p. 101-109

3.8. *D.S. Delion*, R.J. Liotta, R. Wyss, "Exotic Nuclei and Nuclear Particle Physics", Mamaia, Romania, 2005, Eds. S. Stoica, L. Trache, R.E. Tribble, World Scientific,Singapore(2005)p125-132

3.9. *D.S. Delion*, A. Sandulescu, "Dynamics and Phase Transitions in Nuclei", Predeal, Romania, 2006, Eds. A.A. Raduta, V. Baran, I,I, Ursu, World Scientific, Singapore (2006) p.497-514

3.10. *D.S. Delion*, R.J. Liotta, R. Wyss, Proceedings of the International Conference "PROCON07", Lisbon, 2007, Eds. L.S. Ferreira, P. Arumugan, AIP (2007) p. 47-52

3.11. *D.S. Delion*,"Exotic Nuclei and Nuclear/Particle Astrophysics", Sinaia, Romania,2007, Eds. L.Trache, S.Stoica, American Institute of Physics (2007) p.147-155

B3. Scientific contributions from the period 2001-2011 (max. 3 pages)

Articles

1. ***D.S. Delion*****,** A. Sandulescu, *Towards a selfconsistent alpha-decay theory,*
Journal of Physics G **28**, 617-625 (2002). **14 citations**

ABSTRACT *We show that the α-particle preformation factors in Os, Pt, Hg isotopes given by the standard shell model are not consistent with the barrier penetrabilities. The internal cluster amplitude and the outgoing Coulomb wavefunction should have the same logarithmic derivatives for the experimental Q-value. The usual shell model wavefunctions are not able to satisfy this condition along any isotopic chain. In order to correct this deficiency we diagonalize the mean field using a single particle basis with two harmonic oscillator parameters. In order to obtain correct tails of the wavefunctions, the second harmonic oscillator parameter should increase with the mass number. This is consistent with the suppression of α-clustering by increasing the p–n asymmetry.*

2. ***D.S. Delion*****,** R.J. Liotta, R. Wyss, *High spin states and shape changes in odd-odd proton emitters,* Physical Review C **68**, 054603/1-4 (2003). **6 citations**

3. *D.S. Delion*, A. Sandulescu, W. Greiner, *Evidence for alpha-clustering in heavy and superheavy nuclei,* Physical Review C **69**, 044318/1-19 (2004). **18 citations**

ABSTRACT *We analyze the α-decay between ground states along α-chains in deformed heavy and superheavy nuclei, by using the pairing approach. We show that the derivative of the preformation amplitude is practically a constant along any α-chain, while that of the outgoing wave function changes exponentially upon the Coulomb parameter. This leads to the breakdown of the continuity equation and therefore to wrong decay widths. We correct this deficiency by considering a cluster factor in the preformation amplitude, depending exponentially upon the Coulomb parameter. Thus, four-body correlations, connected with the radial shape of the preformation factor, are directly evidenced by the α-decay systematics. Moreover, this procedure, in principle, fully determines the Q value and α-clustering, being an important development in the a-decay theory. It turns out that the isotopes close to the region N>126 and superheavy nuclei have a stronger clustering behavior.*

4. ***D.S. Delion*****,** R. Wyss, D. Karlgren, R.J. Liotta, *Proton emission from triaxial nuclei,*
Physical Review C **70**, 061301(R)/1-5 (2004). **6 citations**

5. ***D.S. Delion*****,** R.J. Liotta, R. Wyss, *Theories of proton emission,*
Physics Reports **424**, 113-174 (2006). **14 citations**

6. ***D.S. Delion*****,** R.J. Liotta, R. Wyss, *Systematics of proton emission,*
Physical Review Letters **96**, 072501/1-4 (2006). **19 citations**

ABSTRACT *A very simple formula that relates the logarithm of the half-life, corrected by the centrifugal barrier, with the Coulomb parameter in proton decay processes is given. The* *corresponding experimental data lie on two straight lines which appear as a result of a sudden change in the nuclear shape marking two regions of deformation independently of the angular momentum of the outgoing proton. This feature provides a powerful tool to assign experimentally quantum numbers in proton emitters.*

7. *D.S. Delion*, S. Peltonen, J. Suhonen, *Systematics of the alpha decay to rotational states,*
Physical Review C **73**, 014315/1-10 (2006). **25 citations**

ABSTRACT *We analyze α-decays to rotational states in even-even nuclei by using the stationary coupled channels approach. The α-nucleus interaction is given by a double folding procedure using M3Y plus Coulomb nucleon-nucleon forces. We use a harmonic oscillator repulsive potential with one independent parameter, to simulate the Pauli principle. The decaying state is identified with the first resonance inside the resulting pocket-like potential. We obtained a good agreement with existing experimental data concerning total half-lives and α-decay widths to* $J = 2^+$ *and* 4^+ *states. We found out that the computed widths to excited states are correlated with the corresponding deformation parameters. We conclude that the α-decay fine structure is a sensitive tool to probe fundamental aspects of the effective nuclear interaction and its dependence on the α-clustering.*

8. *D.S. Delion*, R.J. Liotta, R. Wyss, *Alpha decay of high spin isomers in superheavy nuclei,*
Physical Review C **76**, 044301/1-8 (2007). **17 citations**

9. *D.S. Delion,* *Universal decay rule for reduced widths,*
Physical Review C **80**, 024310/1-7 (2009). **10 citations**

ABSTRACT *Emission processes including α-decay, heavy cluster decay, proton and di-proton emission are analyzed. By using a shifted harmonic oscillator plus Coulomb α-daughter interaction it is possible to derive a linear relation between the logarithm of the reduced width squared and the fragmentation potential, defined as the difference between the Coulomb barrier and the Q value. This relation is fulfilled with a good accuracy for transitions to ground states, as well as to low-lying* 2^+ *excited states. The well-known Viola-Seaborg rule, connecting half lives with the Coulomb parameter and the product between fragment charge numbers, as well as the Blendowske scaling rule, connecting the spectroscopic factor with the mass number of the emitted cluster, is understood in terms of the fragmentation potential. It is shown that the two regions in the proton emission systematics are connected to the corresponding regions of the fragmentation potential.*

10. *D.S. Delion*, R. Wyss, R.J. Liotta, Bo Cederwall, A. Johnson, and M. Sandelius,
Investigation of proton-neutron correlations close to the drip line,
Physical Review C **82**, 024307/1-8 (2010). **1 citation**

ABSTRACT *Proton-neutron (p-n) correlations above the Z=50 shell closure are investigated with the aim of understanding the behavior of the* 2^+ *and* 4^+ *states in Te and Xe isotopes, which remain at a rather constant energy as one approaches the shell closure at N=50. Our calculations reveal* *that standard QRPA calculations, involving quadrupole-quadrupole (QQ) interaction with constant strengths, cannot explain this feature. It turns out that an increased p-n QQ interaction increases the collectivity (i.e., B(E2) values) when approaching the N=50 region, whereas an increased p-n pairing interaction decreases the collectivity. Thus the ratio between the B(E2) value and* 2^+ *energy is a "fingerprint" of p-n collectivity and it should be determined in future experiments concerning light Te isotopes. Based on this criterion, we conclude that the available experimental data indicate an enhanced p-n pairing interaction by approaching doubly magic Z=N=20 and Z=N=28 regions.*

Monographs

D.S. Delion, *Theory of particle and cluster emission,* Springer-Verlag, Berlin, Heidelberg (2010)

ABSTRACT *Nowadays experimental nuclear physics pushes its limits towards highly unstable nuclei. The theoretical description of proton-rich and neutron-rich nuclei or superheavy elements has become an important part of the modern nuclear physics. The main tool to investigate such unstable nuclei concerns radioactive decays, from proton emission to fission processes. We review the main theoretical methods describing decay processes induced by the strong interaction, like Coupled channels method for Gamow resonances, R-matrix theory, Distorted wave approach, Semiclassical approach, Multi step and Two center shell model. Thus, most of the book is addressed to a broad audience within the nuclear physics community. Secondly, this book is an attempt to clarify some fundamental aspects connected with the fine structure or anisotropy in α-decay and ternary cold fission. Finally, the self consistent microscopic theory of the α-decay is analyzed.*

Libraries and university libraries where the book can be found:

1) CERN document server: http://cdsweb.cern.ch/record/1338780
2) British library online: http://direct.bl.uk/bld/PlaceOrder.do?UIN=283403268&ETOC=RN
3) Wolbach library: http://www.cfa.harvard.edu/lib/newbooks/Newbookslatest.pdf:
4) Books unlimited: http://www.booksunlimited.ie/Author/Delion-J.-F..htm
5) Heidelberg University: http://www.ub.uni-heidelberg.de/helios/nel_inst/00/PY/2011_02_68.html
6) Univ. of Notre Dame: http://chemistry.library.nd.edu/about/recentacquisitions11/Mar8.shtml
7) Delft University of Technology:
http://discover.tudelft.nl:8888/recordview/view?recordId=aleph%3A000890097&language=en
8) Ecole Polytechnique Federale de Lausanne:
http://library.epfl.ch/en/ebooks/?pIndex=springer&sType=sim&sk=3800
9) Ryerson University:
https://www.runner.ryerson.ca/Library/newtitles/index.cfm?num=25&sort=a&f_id=5&st=101
10) McMaster University: http://libcat.mcmaster.ca/
index.jsp?sid=12C25BCF5386&Ne=20563&Tab=2&N=27481+4294964933

C. Project description (max. 10 pages)

“N-BODY CORRELATIONS IN EXOTIC NUCLEAR SYSTEMS”

One of the most active fields of the modern nuclear physics is the investigation of exotic nuclear systems, like proton/neutron rich nuclei by using radioactive beams and fission, or superheavy elements through fusion and α-decay processes. An intense research activity of exotic nuclei is performed in many international laboratories (GANIL-Caen, GSI-Darmstadt, JINR-Dubna). Most of these nuclei are weakly bound systems of few nucleons, coupled to a relatively more stable core. Two-body strong interaction in a nuclear medium get transformed into a **few body correlation** of strongly interacting nucleons like **pairing (N=2)** or **quarteting (N=4),** playing an important role in nuclear stability with respect to various decay channels. Another exotic nuclear system is stellar matter, constituting the major baryonic component of massive objects in the universe, as exploding supernovae cores and neutron stars. Simple estimates show that nuclear stellar matter under certain conditions becomes unstable versus a **many-body ($N\sim10^3$) correlated** “pasta phase”.

These aspects are analyzed by our project within three main work-packages, namely:

WP1. Clusterisation: from finite nuclei to stellar matter;

WP2. Pair correlations of fissioning scission configurations;

WP3. Probing nuclear correlations by ternary emission processes

This project continues some traditional research directions in Romania, namely particle and cluster emission, fission and heavy ion reactions. It supposes an intense international cooperation with prof. Peter Schuck (Institut de Physique Nucleaire, Orsay, France), prof. Roberto J. Liotta (Royal Institute of Technology, Stockholm, Sweden), prof. Jouni Suhonen (University of Jyväskylä, Finland), and prof. Francesca Gulminelli (Laboratoire de Physique Corpusculaire, Caen, France).

C1. SCIENTIFIC CONTEXT AND MOTIVATION

WP1. Clusterisation: from finite nuclei to stellar matter

a) The α-particle, as the lightest shell structure, has enough large binding energy to “survive” as a correlated cluster in various nuclei [1]. The role of α-clusters in the structure of light nuclei is a well established fact [2]. The coexistence of clusters with mean-field-type configurations in the ground and excited states of the α-like nuclei ^{8}Be, ^{12}C, ^{16}O or ^{20}Ca was evidenced by Antisymmetrized Modecular Dynamics [3]. The situation changes in medium and heavy nuclei. Nuclear matter calculations revealed that α-particles can exist only at densities below 10% of the nuclear equilibrium density [4]. Thus, α-particles can appear only at small densities in the nuclear surface region. Standard shell-model calculations using the mean-field plus pairing approach showed that only a small fraction of the absolute α-decay width can be described [5]. Moreover, the analysis of experimental reduced widths evidenced a clear dependence upon the difference between the Coulomb barrier and Q-value. Such a relation can be derived by supposing an α-cluster, described by a Gaussian on the nuclear surface [6]. In a recent paper [7] there were evidenced in ^{212}Po exotic non-natural parity states: 4^-, 6^-, 8^-, connected to the usual natural parity states 4^+, 6^+, 8^+ by strong E1 transitions. Moreover, the intra-band E2 transitions predicted by shell model calculations are by one order of magnitude lower than experimental values. **Thus, an important α-cluster component should exist on the surface of heavy nuclei and theoretical investigations are necessary.**

b) On the other hand, **nuclear clusterization occurs not only in finite cold or excited nuclei, but also in the baryonic matter which constitutes the main component of compact stars** [8,9]. Though present in various amounts over the whole domain of temperatures, isospin asymmetries and densities smaller than the normal nuclear matter density, nuclear clusters manifest the most spectacular behavior around a half of the normal nuclear densities [10]. There, the contrasting effects of Coulomb and surface interaction are responsible for **exotic shapes, generically termed as phasta phases**. From the termodynamical point of view, the coexistence of two competing phases leads to a second-order phase homogeneous (core)-unhomogeneous (crust) matter transition and to the modification of the equations of state. From the astrophysical simulations point of view, the situation is equally important as **clusters may change the propagation of the shock wave following the gravitational collapse and the neutrino opacity, responsible for the star cooling.**

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[2] K. Wildermuth, Y.C. Tang, *Unified Theory of the Nucleus,* Vieweg, Braunschweig (1977).
[3] H. Horiuchi in *Cluster in Nuclei*, Ed. C. Beck (Springer-Verlag, Berlin, 2010) p.57
[4] G. Röpke, M. Schmidt, L. Münchow, H. Schulz, Nucl. Phys. A **399**, 587 (1983).
[5] D.S. Delion, A. Sandulescu, W. Greiner, Phys. Rev. C **69**, 044318 (2004).
[6] D.S. Delion, Phys. Rev. C **80**, 024310 (2009).
[7] A. Astier, P. Petkov, M.-G. Porquet, D.S. Delion, P.Schuck,Phys. Rev. Lett. **104**, 042701 (2010)
[8] J. M. Lattimer and F. Douglas Swesty, Nucl. Phys. A **535**, 331 (1991).
[9] H. Shen, H. Toki, K. Oyamatsu, and K. Sumiyoshi, Nucl. Phys. A **637**, 435 (1998).
[10] G. Watanabe, K. Iida, and K. Sato, Nucl. Phys. A **676**, 455 (2000).

WP2. Pair correlations of fissioning scission configurations

Fission is the main tool in obtaining exotic neutron rich nuclei. **It turns out that pairing correlations in hyper-deformed fissioning systems plays a crucial role.** Let us mention that the evolution of the neutron pair field in fission, leading to neutron rich nuclei characterized by extended neutron distributions, is relevant for astrophysical r-processes. A better understanding of the density dependence of the nuclear pairing interaction is important for the theories of superfluidity in neutron stars [1]. In the simplest approach, one defines a small workspace of pairing active states interacting by matrix elements with a common value, depending on the size of the nuclear system or the numbers of active neutrons and protons. This simple treatment has serious disadvantages: the coupling to continuum states is exaggerated and the parametrization correlated to the size is questionable for very deformed systems. To avoid these problems, actual developments are based on local two-body pairing forces treated in connection with self-consistent mean field calculations. **The most fundamental approach to estimate pairing correlations in some given mean field geometry is the renormalization of the nucleon-nucleon bare force within the G-matrix technique [2].** The less sophisticated models introduce phenomenological pairing interactions [3,4]. Until now only relative schematic pairing interactions were used in describing the dynamics of the fissioning nuclei. The results are strongly dependent upon the size of the used space. **Thus, it is important to apply G-matrix technique to hyper-deformed nuclear mean field configurations, in order to ensure a proper microscopic description of the fission process.**

[1] C.J. Pethick, D.G. Reavenhall, Annu. Rev. Nucl. Part. Sci. **45** (1995).
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WP3. Probing nuclear correlations by ternary emission processes

The angular distribution and decay width of an open **two-body system** can be estimated by using the standard coupled channel procedure, in terms of usual spherical harmonics [1]. **The three-body problem** in continuum is more complex than the two-body one. The necessity to use the three-body dynamics in weakly bound, as well as in open nuclear systems, was triggered by the investigation of several exotic nuclear systems and phenomena like: **ternary fission [2], weakly bound light neutron rich nuclei (Borromean nuclei) [3], simultaneous two-proton emission [4], and 3α-dynamics of Hoyle states in ^{12}C [5].**

Concerning the cold fission accompanied by ternary emission of light clusters (^{4}He, ^{8,10}Be, ^{12,14}C), due to the large mass difference, the motion of the binary heavy system is much slower and the dynamics of the light cluster practically becomes a two-body problem in the field of the hyper-deformed heavy system [1]. The situation changes for Borromean nuclei and two-proton emitters, where the three-body dynamics becomes important [3]. Until now the half life of few two-proton emitters was determined [4]. An intense experimental work in determining their angular distribution is under way [6]. In these nuclei two-body correlations between weakly bound particles play a central role. **Thus, the investigation of weakly bound or open two-particle+core system of nucleons is an important tool in probing two-body correlations at low densities.**

[1] D.S. Delion, *Theory of particle and cluster emission*, Springer-Verlag, Berlin (2010).

[2] A.V. Ramayya, et.al., Phys. Rev. C **57**, 2370 (1998).

[3] M.V. Zhukov, et.al., Phys. Rep. **231**, 151 (1993).

[4] L.V. Grigorenko, M.V. Zhukov, Phys.Rev. C**68**, 054005 (2003); Phys. Rev. C**76**, 014009 (2007)

[5] H. Horiuchi in *Cluster in Nuclei*, Ed. C. Beck (Springer-Verlag, Berlin, 2010) p.57

[6] L.V. Grigorenko, I. A. Egorova, M. V. Zhukov, et.al., Phys. Rev. C **82**, 014615 (2010).

C2. OBJECTIVES

The project has two main objectives, namely:

a) to investigate the role of few-body (N=2,4) correlations in exotic nuclear configurations,

b) to search for possible many-body ($N\sim10^3$) correlations in star matter.

Bellow we will give a short presentation of specific objectives for each work-package.

WP1. Clusterisation: from finite nuclei to stellar matter

a) The first goal of this part of the project is to confirm that **the α-decay and electromagnetic transitions in heavy nuclei, in particular ^{212}Po, can simultaneously be explained by using an α-clustering component in the nuclear wave function**. Thus, we will show that the recently evidenced enhancement of E1 transitions connecting exotic J^- to normal J^+ states [1] and the relative large B(E2) values of intra-band transitions are indeed directly explained by four-body correlations. Recently, the non-natural parity states in ^{212}Po were explained by using **a phenomenological coupled channel analysis**, where an α-particle was coupled to the collective 3^- state in ^{208}Pb [2]. Our main purpose is **to go beyond this phenomenological picture** and to use a **microscopic model** in describing the non-natural parity states. An additional α-clustering component in the single particle basis is necessary to **simultaneously describe electromagnetic and α-transitions in ^{212}Po**. Then, we shall **extend the analysis of the correlation between B(E2)-values and α-decay widths, as an important "fingerprint" of the α-clustering, to other heavy and superheavy nuclei.**

b) The second goal is **the investigation of chemical and thermodynamical properties of clusterized nuclear matter** with temperatures between 0 and 20 MeV, isospin asymmetries between 0 (pure neutron matter) and 0.5 (symmetric nuclear matter) and densities in between 10^6 g/cm^3 and the normal nuclear density, relevant for supernovae and neutron stars. We shall elaborate an analytical model for the mixture clusterized - homogeneous matter and derive the associated equations of states over the whole validity range. The model will be a generalization of Ref. [3] and will additionally allow for a more realistic description of the homogeneous phase, to account for pairing and superfluidity effects and Coulomb treatment beyond the Wigner-Seitz approximation.

[1] A. Astier, P. Petkov, M.-G. Porquet, D.S. Delion,P. Schuck,Phys. Rev. Lett. **104**,042701 (2010).
[2] Y. Suzuki, S. Ohkubo, Phys. Rev. C **82**, 041303(R) (2010).
[3] A.R. Raduta, F.Gulminelli, Phys. Rev. C **82**, 065801 (2010).

WP2. Pair correlations of fissioning scission configurations

Our purpose is to investigate the behavior of effective matrix elements derived from realistic interaction in the pairing channel at hyper-deformations and scission configurations, i.e. for systems composed by nearly touching nuclei behaving as nuclear molecules [1]. We shall search for a possible existence of the "pairing polarization" between two nuclei in contact. Such an effect, given by the mutual pairing influence between fragments, could have a crucial influence on the fission yields and on the half lives of cluster and alpha decays. The phenomenon will be investigated using two formalisms: the G-matrix renormalization technique starting from a realistic interaction [2] and the effective density dependent interaction [3]. The wave function will be obtained within the realistic super-asymmetric Woods-Saxon two center shell model [4]. This shell model is able to treat in a unitary way binary disintegrations in a wide range of mass asymmetries, including fission [5], cluster and α-decay, from the ground state of the parent up to the configuration given by two separated fragments. **New knowledge about the total energy partition during scission processes will be provided.**

[1] D.S. Delion, A. Sandulescu, S. Misicu, F. Carstoiu, W. Greiner, J. Phys. G **28**, 289 (2002).
[2] D.S. Delion, M. Baldo, U. Lombardo, Nucl. Phys. A **593**, 151 (1995).
[3] J. Dobaczewski, W. Nazarewicz, P.-G. Reinheirt, Nucl. Phys. A **693**, 361 (2001).
[4] M. Mirea, Phys. Rev. C **78**, 044618 (2008).
[5] M. Mirea, D.S. Delion, A. Sandulescu, Phys. Rev. C **81**, 044317 (2010).

WP3. Probing nuclear correlations by ternary emission processes

Our objective is to investigate two-body correlations in light exotic nuclei, by using simultaneous two-particle (proton or neutron) emission process. To this purpose we shall develop a general method to estimate the angular distribution of the three-body decaying system, as the main tool to probe the two-body correlations on the nuclear surface, in particular pairing interaction. Let us mention that two-particle emission is "a mirror effect" with respect to the ternary fission, i.e. the binary system of emitted particles is much lighter than the "ternary core". **Thus, our goal is to use a "mirror theory" with respect to the ternary fission in Ref. [1] and to compare the results with the hyper-spherical formalism [2]. We shall analyze the sensitivity of the two-particle angular distribution on mean field parameters and pairing gap for known two-proton emitters and to predict new possible two-particle emitters, including two-neutron and**

deuteron emitters. Our approach will open the possibility to probe the realistic pairing interaction and to use two-body wave function on the nuclear surface for two-particle transfer reactions.

[1] D.S. Delion, A. Sandulescu, W. Greiner, J. Phys. G **29**, 317 (2003).

[2] M.V. Zhukov, et.al., Phys. Rep. **231**, 151 (1993).

C3. METHOD AND APPROACH

WP1. Clusterisation: from finite nuclei to stellar matter

The research methodology of this part of the project has the following **milestones**:

a) Microscopic description of electromagnetic and α-decay widths in ^{212}Po and heavier nuclei.

b) Derivation of the equation of state, describing clustering phenomena in stellar matter.

a) Microscopic description of low lying normal parity states in ^{212}Po is given by coupling low-lying two-proton states in ^{210}Po and two-neutron states in ^{210}Po [1]. These two-particle collective states are described within the so-called Tamm-Dancoff approximation (TDA) and are built on top of the ground state of the double magic nucleus ^{208}Pb. In order to describe exotic non-natural parity states, **we shall generalize this picture by coupling proton and neutron pairs not to the ground state, but to the excited 3^- particle-hole state of ^{208}Pb**. Then, we shall estimate E1 transitions to the corresponding normal parity states and also intra-band E2 transitions. **It will be shown that only by including a Gaussian-like α-clustering component, centered on the nuclear surface, in the single particle basis it is possible to describe electromagnetic transitions.**

In order to compute microscopically the α-decay width we shall generalize the recoupling technique described in Ref. [2], but including an α-cluster component centered on the nuclear surface [3]. It will be shown that **the same α-clustering component describing electromagnetic transitions is also able to describe the absolute value of the α-decay width**.

In the next step we shall extend this analysis to other heavy and superheavy even-even α-emitters, by using the above single particle basis, containing α-clustering components on the nuclear surface. According to Ref. [4], we expect that the strength of the α-clustering component will be proportional to the fragmentation potential, defined as the difference between the Coulomb barrier and Q-value. Alpha-decay widths will be estimated within the mean field plus pairing model [2], while B(E2) values will be estimated by the standard Quasiparticle Random Phase Approximation.

b) Following the recipe proposed in Ref. [5], **we shall describe the mixture homogeneous-clusterized matter by employing a mean field approach coupled to a Fisher-type gas of weekly interacting clusters.** Several parameterization of the nucleon-nucleon interaction potential will be considered in order to trace the impact of the asymmetry energy on the macroscopic observables. Equation of state tables will be eventually generated such as to allow their use in supernovae explosion simulations.

[1] D.S. Delion, J. Suhonen, Phys. Rev. C **61**, 024304 (2000).

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[5] A.R. Raduta, F.Gulminelli, Phys. Rev. C **82**, 065801 (2010).

WP2. Pair correlations of fissioning scission configurations

The following **milestones** describe this part of the project methodology:

a) Computation of the G-matrix elements of the Paris potential for hyper-deformed systems;

b) Investigation of the pairing properties for a fissioning system.

a) In Ref. [1] we used the G-matrix technique to compute the effective interaction in the pairing channel for a spherical Woods-Saxon mean field, starting with the Paris interaction in its separable form [2]. The advantage in using a separable potential is that all involved relations are analytical. **We shall generalize this technique, in order to compute the G-matrix in deformed and hyper-deformed systems of nucleons.** Firstly,we shall systematically investigate the dependence on mean field parameters and the mass number for deformed nuclei. Then, the pairing interaction depending on the interfragment distance will be used to solve the BCS equations for two-center configurations.

b) In the second step we shall analyze the dynamics of the fission process by using the realistic pairing interaction. **This scission configuration will be determined dynamically by using the least action principle [3]**. Shell and pairing corrections will be obtained within the Woods-Saxon two center shell model [4]. To describe realistically the nuclear system, we use five shape degrees of freedom (elongation, necking, deformation of both fragments and mass-asymmetry) [5].

[1] D.S. Delion, M. Baldo, U. Lombardo, Nucl. Phys. A **593**, 151 (1995).

[2] J. Haidenbauer, W. Plessas, Phys. Rev. C **30**, 1822 (1984).

[3] M. Brack, J. Damgaard, A.S. Jensen, H.C. Pauli, et.al., Rev. Mod. Phys. **44**, 320 (1972).

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[5] U. Brosa, S. Grossman, and A. Muller, Phys. Rep. **197**, 167 (1990).

WP3. Probing nuclear correlations by ternary emission processes

The **milestones** of this part of the project methodology are:

a) Derivation of coupled channel system of equations describing two-particle emission;

b) Investigation of the angular distribution of emitted particles.

a) We shall compute the correlated microscopic two-body wave function on the surface of the core nucleus. For simplicity, the pairing two-body force with a constant strength will be used. The external wave function will be expanded in terms of relative and center of mass spherical harmonics. A system of coupled equations for relative and center of mass radial wave functions of emitted particles will be derived. It has a similar structure with respect to the system of equations describing ternary fission in Ref. [1], but we have a “mirror mass picture”, i.e. the binary system of emitted particles is much lighter than the “ternary emitted core ”.

b) In the next step we shall find narrow (Gamow) outgoing resonances of the system, by matching internal and external solutions on the nuclear surface. Then, we shall determine the two-particle angular distribution and decay width. The sensitivity of these observables versus the mean field parameters and pairing gap will be investigated. A comparison to the coupled channel method using hyperspherical coordinates [2] will be performed.

[1] D.S. Delion, A. Sandulescu, W. Greiner, J. Phys. G **29**, 317 (2003).

[2] L.V. Grigorenko, R.C. Johnson, J.K. Mukha, et.al., Phys. Rev. C **64**, 054002 (2001).

WORK PLAN

The team contains the leader, two senior researches (Participant 1 and 2) and two students.

Year	Work-pack.	Task	Responsible/ Participants	Man-months	Delivra-bles
2011	WP1	Analysis of the α-clustering influence on electromagnetic and α transitions in ^{212}Po	D.S. Delion Participant 1	3 2	-Report Dec.10 -1 paper
2012	WP1	Investigation of statistical ensemble (in)-equivalence in stellar matter	Participant 2	5	-Report Sept. 20 -3 papers
	WP2	Generalization of the G-matrix method in computing pairing interaction for deformed and hyper-deformed configurations	D.S. Delion Participant 1 Student 1	5 5 4	
	WP3	Description of ternary emission processes within the three-body dynamics.	D.S. Delion Student 2	5 4	
2013	WP1	Investigation of the α-clustering properties in heavy and superheavy nuclei	D.S. Delion	3	-Report Sept. 20 -3 papers
	WP2	Systematics of pairing properties for deformed nuclei within the G-matrix approach	D.S. Delion Participant 1 Student 1	2 5 4	
	WP3	Probing surface nuclear correlations in exotic nuclei by two-particle emission process	D.S. Delion Participant 2 Student 2	5 5 4	

2014	WP1	Derivation of a new equation of state for stellar matter with a smooth behavior over the whole validity range	Participant 2	5	-Report Sept. 20 -2 papers
	WP2	Computation of fission barriers within the two center shell model by using a realistic pairing interaction	D.S. Delion Participant 1	5 5	

The final report will be given on September 20, 2014.

C4. IMPACT, RELEVANCE, APPLICATIONS

We expect that the impact of our results will increase the international visibility of the team leader and participants. The relevance and applications of our results concern the following aspects:

(a) We shall give the first microscopic explanation of the enhancement for both electromagnetic and α-transitions from ^{212}Po, by using an α-cluster component in single-particle wave functions. A similar correlation, as an “α-clustering fingerprint”, will be investigated in heavy and superheavy nuclei.

(b) We shall derive a new equation of state containing clustering features for stellar matter, with an important impact in the understanding of the star cooling process.

(c) We shall solve pairing equations for hyper-deformed fissioning configurations, by using an effective pairing potential, derived from the realistic two-body Paris interaction. New knowledge about the total energy partition during scission processes will be provided.

(d) We shall develop a coupled channel method, similar to the ternary fission approach, describing two-particle (proton, neutron, or deuteron) emission, by using as a boundary condition the two-body wave function on the nuclear surface. The sensitivity of the angular distribution versus mean field and gap parameters will be investigated. A better knowledge concerning nuclear interaction at low densities on the surface of exotic nuclei, close to proton/neutron stability lines, will be provided. Further applications for realistic pairing interaction and two-particle transfer reactions are possible.

(e) In the context of the academic impact, two students at the Theoretical Physics Department - Bucharest University, will be involved in this project, as part of the Master program.

C5. RESOURCES AND BUDGET

Material resources: 3 Desktop PC (2,4 GHz, 4Gb RAM, 250Gb HDD), 3 Laser Jet printers

Human resources: team leader, two senior researcher, two students

Breakdown Budget (lei)

Budget chapter (expenses)	2011 (lei)	2012 (lei)	2013 (lei)	2014 (lei)	Total (lei)
Salaries	**80.000**	**330.000**	**330.000**	**230.000**	**970.000**
Inventory	**-**	**5.000**	**5.000**	**5.000**	**15.000**
Mobility	**-**	**5.000**	**5.000**	**5.000**	**15.000**
Overhead	**40.000**	**170.000**	**170.000**	**120.000**	**500.000**
Total	**120.000**	**510.000**	**510.000**	**360.000**	**1.500.000**

Inventory: 3 ultra-light laptops (1,5 Kg; 2,4 Ghz; 8Gb RAM; 500Gb HDD), consumables

Mobility: travel expenses for 3-4 flight tickets/year within international collaborations

Breakdown Budget (euro)

Budget chapter (expenses)	Total (euro) (1 leu=4.3 euro)
Salaries	**225.581**
Inventory	**3.488**
Mobility	**3.488**
Overhead	**116.280**
Total	**348.837**

The information in this application is hereby certified to be correct.

Project leader,

Last name, first name: Delion Doru-Sabin

Signature:

Date: April 30, 2011