Date identificare proiect:

Cod: 160

Director proiect: Radu A. Gherghescu

Proiect: IDEI-124

Titlu: *Sinteza si stabilitatea nucleelor supragrele*

http://proiecte.nipne.ro/pn2/index.php?id=42

Acronim: SINS

Data incepere / finalizare proiect: 2007-10-01 / 2010-09-30

Valoarea proiectului: 1000000 RON

Institutia: Institutul National de Cercetare si Dezvoltare pentru Fizica si Inginerie Nucleara Horia Hulubei

MEMBRI: Director proiect: Radu Alexandru GHERGHESCU

Cercetator cu experienta: Dorin N. POENARU

Tineri cercetatori (doctoranzi): Mihaela Raportaru

Bogdan Popovici

Radu.Gherghescu@nipne.ro

REZUMATUL PROIECTULUI

Scopul principal al proiectului este dezvoltarea unei metode teoretice de caracterizare a fuziunii si fisiunii nucleare aplicabile la sinteza si dezintegrarea nucleelor supragrele. Subiectul este in fruntea preocuparilor grupurilor de fizica nucleara teoretica si experimentala. Recent elementul supragreu nou sintetizat Z=110 a fost numit Darmstadtium (Ds), iar cercetarile continua pentru extinderea regiunii de masa nucleara. Pentru a explica stabilitatea nucleelor supragrele cat si pentru a gasi cele mai favorabile canale de fuziune este necesar un model specializat capabil sa descrie fenomenele binare de sinteza si dezintegrare a acestor sisteme. Proiectul propus porneste de la cel mai dezvoltat model cu doua centre deformate construit de autorii acestei propuneri. Se urmareste statica si dinamica proceselor de sinteza si dezintegrare prin aplicarea unei metode macroscopic-microscopica binara. Modelul cu doua centre deformate va genera nivelele uniparticula protonice si neutronice necesare calculului corectiilor de paturi si imperechere. Partea macroscopica va fi obtinuta prin model picatura de lichid incarcata de tip Yukawa+exponentiala. Dinamica procesului va fi obtinuta prin calculul tensorului de inertie in model cranking binar, folosind pentru prima data nivelele potentialului de doua centre si teoria BCS adaptata la efectele de imperechere. Prin minimzarea multidimensionala a integralei actiunii se va obtine traiectoria optima de fuziune si fisiune pentru toate perechile tinta-proiectil posibile in sinteza unui nucleu supragreu. Algoritmul va fi repetat pentru un domeniu larg de numere atomice intre Z=108 si 130. Perechile cu valori maxime ale penetrabilitatii WKB vor fi sugerate experimentatorilor pentru a fi folosite in reactiile de sinteza.

Obiective si activitati si gradul de realizare

2007

Obiectiv: 1. Energia de deformare macroscopica pentru forme de fuziune

Activitati:

1.1 Calculul energiei Coulomb pentru 2 sferoizi intersectati 1.2 Energie Yukawa si totala de deformare pentru forme de fuziune

Grad de realizare: integral

Rezultate obtinute: Comunicare la conferinta internationala

2008

Obiectiv:

1. Schemele de nivele protonice si neutronice pentru forme de fuziune

Activitati:

1.1 Calculul nivelelor uniparticula pentru protoni si neutroni

1.2 Variatia independenta a deformarilor sferoidale in regiunea de suprapunere. Grad de realizare: integral

Obiectiv:

2. Variatia densitatii de sarcina in configuratia tinta-proiectil intersectate

Activitati:

2.1 Variatia numarului de protoni din sferoidul usor si a energiei coulombiene

2.2 Calculul nivelelor uniparticula pentru deformarea data

Grad de realizare: integral

Obiective si activitati si gradul de realizare

Obiectiv:

3. Energia totala de deformare pentru forme de fuziune

Activitati:

3.1 Calculul corectiilor de paturi protonice si neutronice

3.2 Calculul energiei de imperechere

3.3 Calculul energiei de deformare totala

Grad de realizare: integral

2009

Obiectiv:

1. Tensorul de inertie

Activitati:

1.1 Calculul elementelor de matrice ale hamiltoniainului in functie de variabilele de deformare

1.2 Calculul componentelor tensorului de masa

Grad de realizare: integral

Obiectiv:

2. Minimizarea integralei actiunii

Activitati:

2.1 Calculul integralei actiunii in spatiul de deformare

2.2 Minimizarea numerica pe grila multidimensionala de deformare a integralei actiunii

Grad de realizare: integral

Obiective si activitati si gradul de realizare

Obiectiv:

3. Penetrabilitati si sectiuni eficace de fuziune in sinteza nucleelor supragrele

Activitati:

3.1 Calculul penetrabilitatilor WKB

3.2 Calculul sectiunilor eficace

Grad de realizare: integral

Stadiul realizarii indicatorilor de performanta dec. 2007–aprilie 2010 – Articole ISI:

1. R. A. Gherghescu, D. N. Poenaru, W. Greiner, M. Raportaru, B. Popovici, *Charge density influence on macroscopic deformation energy*
   International Journal of Modern Physics E, (2010) in print. Factor ISI= 0.492
   http://www.worldscinet.com/ijmpe/
2. R. A. Gherghescu, D. N. Poenaru, A. Solovyov, W. Greiner, *Hemispheroidal atomic clusters on planar surfaces*
   Physica E 42, 1555-1562 (2010). Factor ISI=1.23
   http://www.elsevier.com/locate/physe.
3. R. A. Gherghescu and N. Carjan, *Two and three fragment emission from Z=120 isotopes*
   Journal of Physics G36, 025106 (2009). Factor ISI: 5.270
   http://iopscience.iop.org/0954-3899/
4. D. N. Poenaru, R. A. Gherghescu and W. Greiner, *Special properties of* ^{264}*Fm*
   Journal of Physics G, 125101 (2009), Factor ISI: 5.270
   http://iopscience.iop.org/0954-3899/
5. D. N. Poenaru and W. Greiner, *Extension of superasymmetric fission theory*
   Nuclear Physics A 834, 163-166 (2009) , Factor ISI: 1.959
   http://elsevier.com/locate/nuclphysa
6. R. A. Gherghescu, D. N. Poenaru and W. Greiner, *Proton gap due to the necking potential*
   Physical Review C78, 024604 (2008). Factor ISI: 3.124
   http://prc.aps.org/

Stadiul realizarii indicatorilor de performanta dec. 2007–aprilie 2010 - Articole ISI:

7. R. A. Gherghescu, D. N. Poenaru and N. Carjan, *Neck influence on fission paths*
Physical Review C77, 044607 (2008). Factor ISI: 3.124
http://prc.aps.org/
8. R. A. Gherghescu, D. N. Poenaru and W. Greiner, *Binary and ternary emission from superheavy nuclei*
International J. of Modern Physics E17, 2221 (2008), Factor ISI: 0.492
http://www.worldscinet.com/ijmpe/
9. D. N. Poenaru and W. Greiner, *Cluster radioactivity - past, present and future*
International Journal of Modern Physics E17, 2255 (2008). Factor ISI: 0.492
http://www.worldscinet.com/ijmpe/
10. R. A. Gherghescu, D. N. Poenaru, A. Solovyov and W. Greiner, *Deformed shell closures*
International Journal of Modern Physics B22, 4917 (2008), Factor ISI: 0.684
http://www.worldscinet.com/ijmpb/
11. D. N. Poenaru, R. A. Gherghescu, N. Carjan, *Alpha-decay lifetimes semiempirical relationship including shell effects*,
Europhysics Letters 77 (2007) 62001. Factor ISI 2007: 2.206
http://epljournal.edpsciences.org/
12. D. N. Poenaru, R. A. Gherghescu, I. H. Plonski, W. Greiner, Int. J. Mod. Phys. E 16 (2007) 995-1007. Factor ISI: 0.684 http://www.worldscinet.com/ijmpe/

1. R. A. Gherghescu, D. N. Poenaru, *Neck influence on fission paths*. Lectie invitata, in Exotic Nuclei and Nuclear/Particle Astrophysics (II), (Proc. Carpathian Summer School of Physics, Sinaia, Romania, 2007) Eds. L. Trache and S. Stoica (American Institute of Physics (AIP) Conference Proceedings No. 972, Melville, NY, 2008) pp. 455-459.
2. D. N. Poenaru, *Shell corrections stabilizing superheavy nuclei and semi-spheroidal atomic clusters*. Invited talk. Published in Exotic Nuclei and Nuclear/Particle Astrophysics (II), (Proc. Carpathian Summer School of Physics, Sinaia, Romania, 2007) American Institute of Physics (AIP) Conference Proceedings No. 972, Melville, NY, 2008, pp. 165-173, Eds. L. Trache and S. Stoica, ISBN 978-0-7354-0490-8.
3. D. N. Poenaru and W. Greiner, *Fission approach to alpha-decay of superheavy nuclei*, Invited talk, Published in Fission and Properties of Neutron-Rich Nuclei (Proc. Fourth International Conference, Sanibel Island, FL, USA, 2007) World Scientific, Singapore, 2008, pp. 321-328, Eds. J. H. Hamilton, A. V. Ramayya, H. K. Carter, ISBN 978-981-283-342-6.
4. D. N. Poenaru, W. Greiner, *Extension of superasymmetric fission theory from cluster decay to nanophysics*, Invited talk, The 10th International Conference on Nucleus-Nucleus Collisions, Beijing, China, 16-21 August, 2009, to be published.

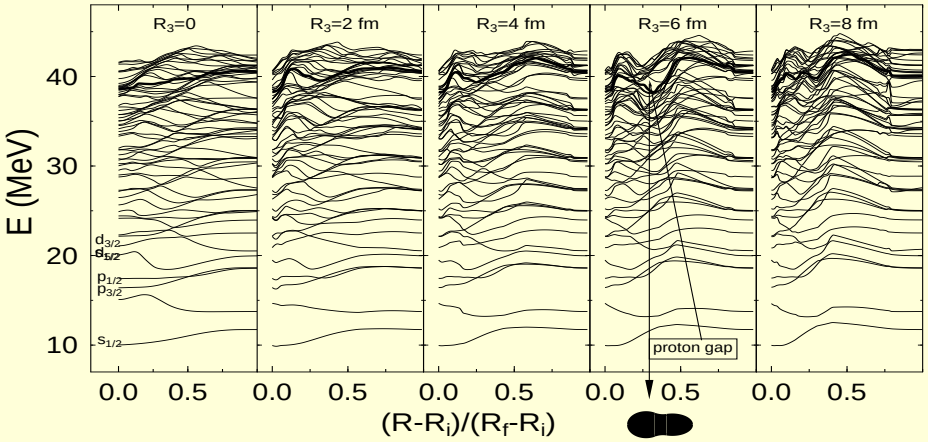
Baza teoretica a proiectului IDEI-124

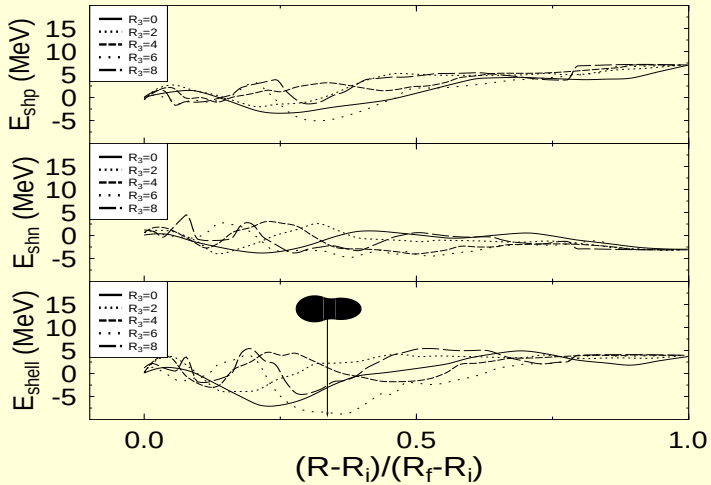
In cadrul proiectului IDEI 124 am dezvoltat metoda macroscopic-microscopica BINARA. Modelul corespunzator de calcul al energiei permite tranzitia de la un sistem cuantic la doua gropi de potential independente (fisiune) precum si trecerea de la doua sisteme independente (tinta-proiectil) la unul singur format prin suprapunerea celor doua (fuziune).

Metoda dezvoltata foloseste modelul in paturi cu doua centre deformate, ai carui autori sunt membrii acestui proiect. Modelul se bazeaza pe suprapunerea partiala a doua potentiale Nilsson si este astfel singurul capabil sa descrie influenta a doua fragmente in cadrul configuratiilor binare de fuziune sau fisiune.

Rezultate noi, originale in corespondenta cu obiectivele propuse

2008 - Obiective 1, 2:
Schemele de nivele protonice si neutronice pentru forme de fuziune si fisiune
Phys. Rev. C78, 024604 (2008)
Int. J. Mod. Phys. B22, 4917 (2008)





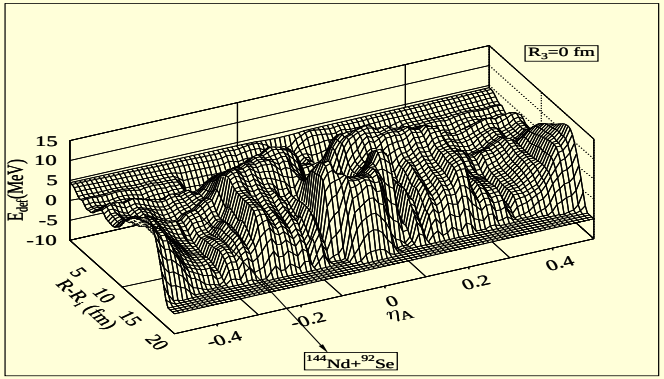
Schemele de nivele protonice pentru diferite raze R_3 ale gatului.
Variatia corectiilor de paturi protonice E_{shp}, neutronice E_{shn} si totale E_{shell} cu distanta redusa intre centre
NOU: Gap protonic datorat corectiilor de paturi la gatuire, care asigura metastabilitatea unei stari izomere de fisiune.

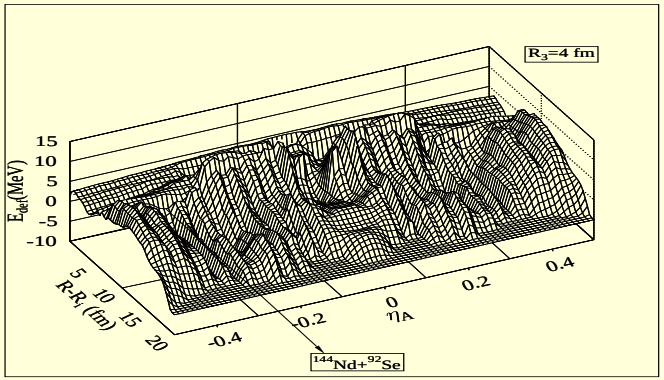
Rezultate noi, originale in corespondenta cu obiectivele propuse

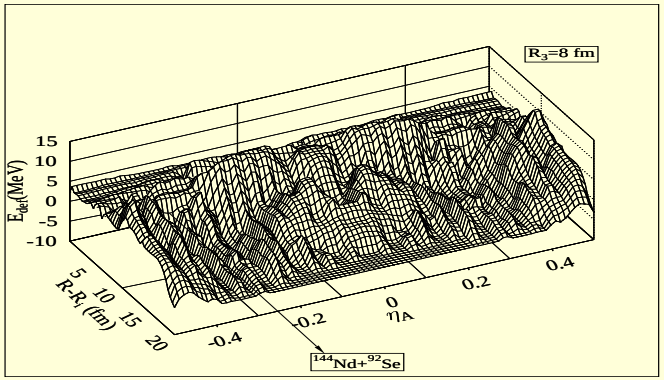
2007 - Obiectiv unic:
Energia de deformare macroscopica pentru pentru forme binare

2008 - Obiectiv 3:
Energia totala de deformare pentru configuratii binare
Phys. Rev. C77, 044607 (2008)

Suprafete de energie potentiala rezultate din minimizarea integralei actiunii.
NOU: Canalul ^{144}Nd+^{92}Se, evidentiat experimental in fisiunea ^{236}Pu la Geel (Belgia) si Strasbourg (Franta) dar neexplicat teoretic pana acum.

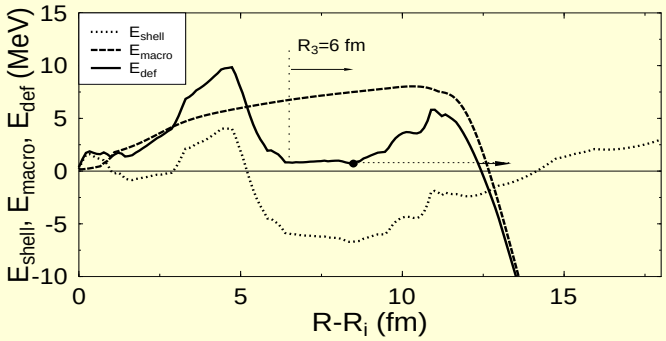




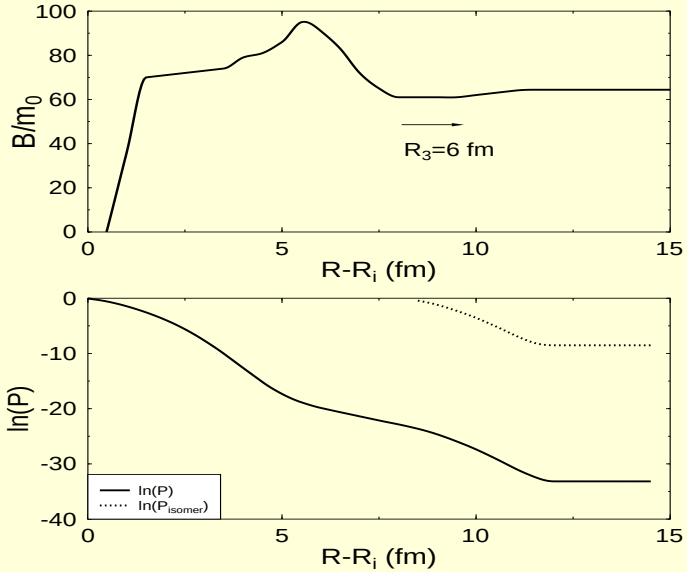


Rezultate noi, originale in corespondenta cu obiectivele propuse

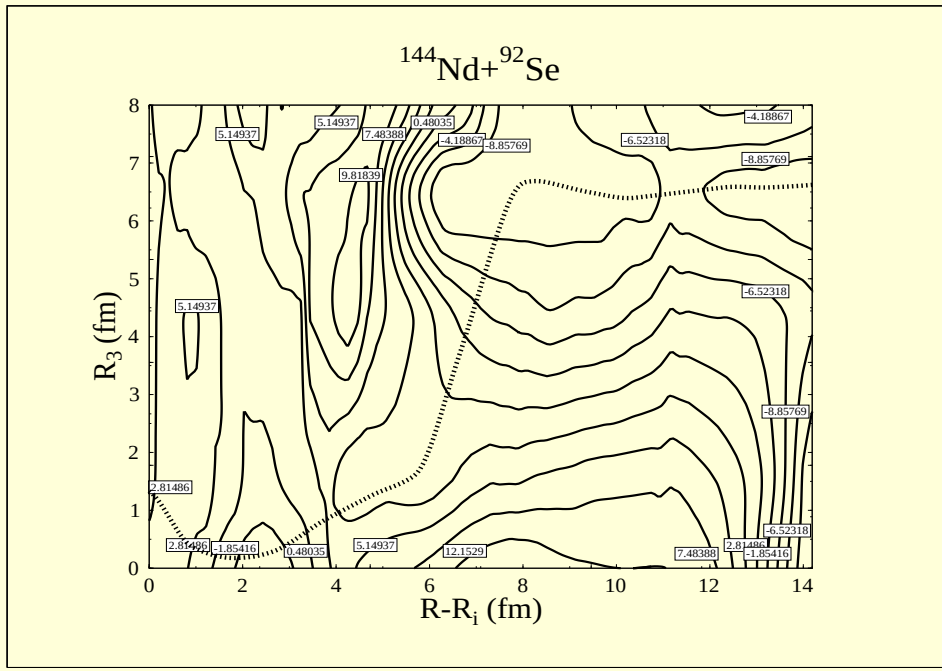
2009 - Obiectiv 2, 3:
Calculul integralei actiunii pentru fisiune.
Minimizarea multidimensionala si calculul penetrabilitatilor
Phys. Rev. C77, 044607 (2008)
J.Phys. G 36, 125101 (2009)



Energia totala de deformare, corectii de paturi si LDM.
Variatia tensorului de inertie pe parcursul de fisiune.
variatia penetrabilitatii in calcul WKB.
NOU: Influenta parametrului de gat R_3
asupra dinamicii (WKB) in model cuantic BINAR.



2009 - Obiectiv 2, 3:
Minmizarea integralei actiunii in spatiul multidimensional.
Calculul traiectoriei dinamice de fuziune si fisiune
pentru nuclee grele si supragrele.
J.Phys. G 36, 125101 (2009)
J.Phys. G 36, 025106 (2009)



Traiectoria dinamica a canalului de fisiune in functie de raza gatului R_3 si distanta intre centre $R - R_i$ variatia penetrabilitatii in calcul WKB.
NOU: Iesirea din bariera NU se produce la R_3=0 conform dinamicii (WKB) in model cuantic BINAR.

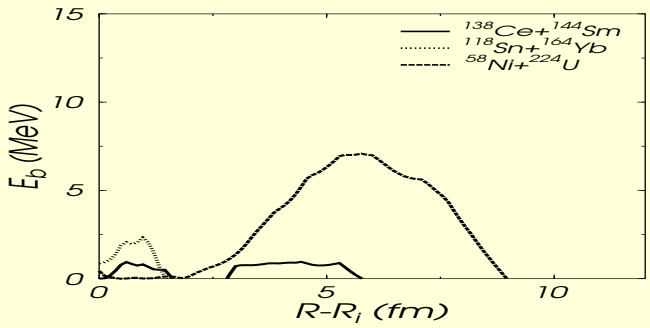
Rezultate noi, originale in corespondenta cu obiectivele propuse

2009 - Obiectiv 2, 3:

Bariere de fuziune si fisiune pentru nuclee grele si supragrele.

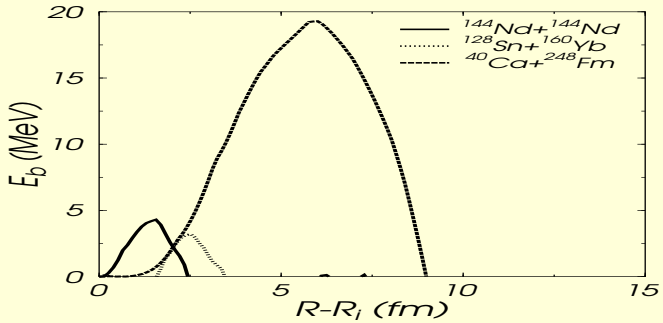
J.Phys. G 36, 125101 (2009)

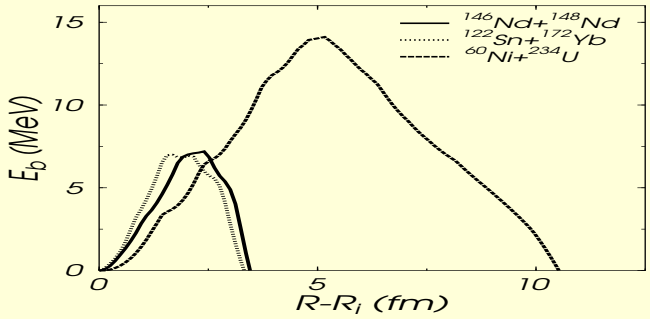
J.Phys. G 36, 025106 (2009)



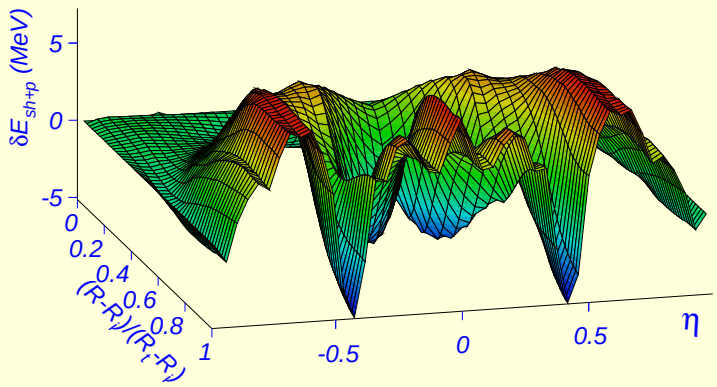
Bariere de fisiune ale nucleelor $^{282,288,294}120$ pentru 3 cele mai favorizate canale de dezintegrare.

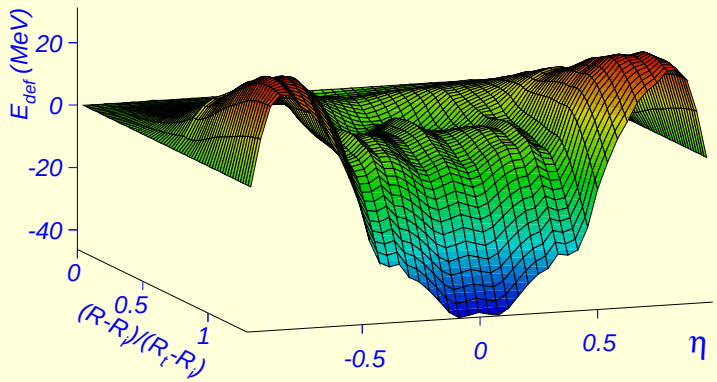
NOU: Canalul Sn este favorizat fata de canalul simetric datorita efectelor de paturi.





Vai reci pe suprafete de energie potentiala si noile supragrele





Suprafete de energie potentiala pentru supragreul ^{294}118. SUS: corectii de paturi si imperechere calculate folosinf cel mai perfectionat model cu 2 centre dezvoltat de noi. JOS: energia de deformare totala. Asimetria de masa $\eta = (A_1 - A_2)/A$.

Daca reactia de fuziune are loc in lungul vaii reci corespunzatoare unei tinte dublu magice sau vecine ($\eta \simeq 0.41$ in figura), nucleul format are o energie de excitatie minima si dupa evaporarea unui neutron rezulta un supragreu identificat de obicei prin emisie α. NOU: Am obtinut valea Pb cu modelul nostru cu doua centre

Importanta proiectului: Noile elemente supragrele sintetizate la GSI Darmstadt (Gottfried Münzenberg, Sigurd Hofmann et al.)

107 Bh Bohrium (^{54}Cr + ^{209}Bi$_{126}$ $\longrightarrow$ ^{263}Bh*)

108 Hs Hassium (^{58}Fe + ^{208}Pb$\longrightarrow$ ^{266}Hs*)

109 Mt Meitnerium (^{58}Fe + ^{209}Bi$\longrightarrow$ ^{267}Mt*)

110 Ds Darmstadtium (^{62}Ni + ^{208}Pb$\longrightarrow$ ^{270}Ds*)

111 Rg Roentgenium (^{64}Ni + ^{209}Bi$\longrightarrow$ ^{273}Rg*)

112 Cn Copernicum sau Copernicium (IUPAC va decide in cursul anului viitor) (^{70}Zn + ^{208}Pb$\longrightarrow$ ^{278}Cn*) precum si elementul 113 sintetizat la RIKEN (Kosuke Morita et al.)

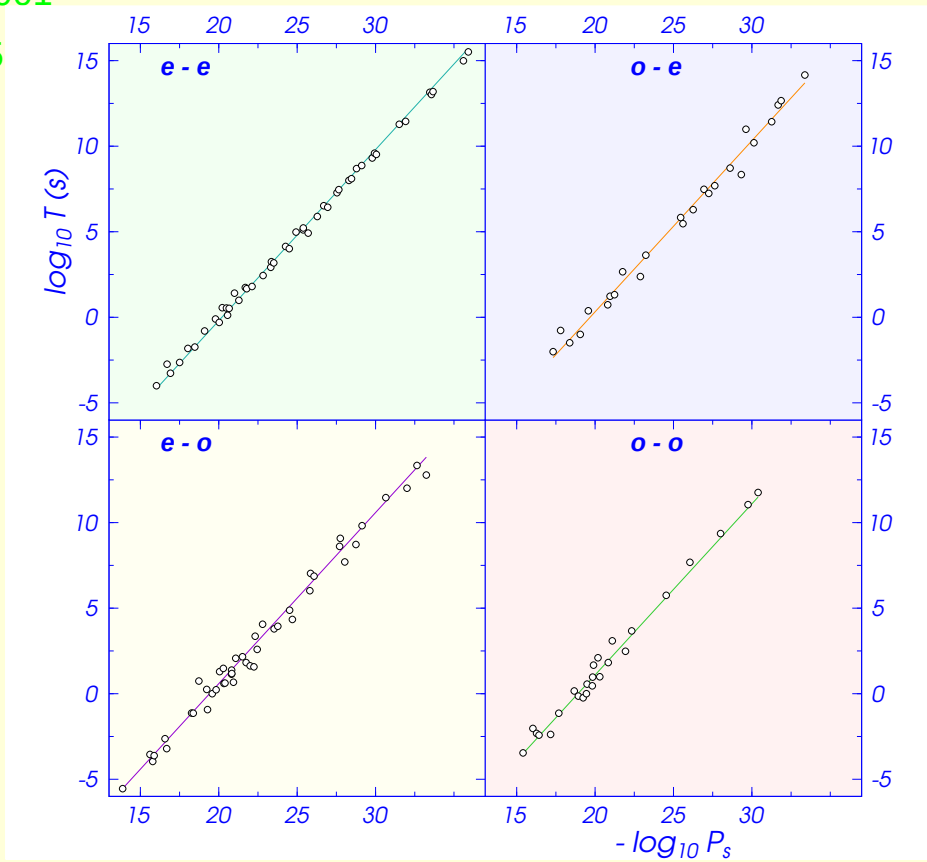
113 (^{70}Zn + ^{209}Bi$\longrightarrow$ ^{279}113*)

au fost produse folosind tinte de ^{208}Pb ($Z = 82$, $N = 126$) sau ^{209}Bi ($Z = 83$, $N = 126$).

Durate de viata fata de emisia α. Nuclee grele si supragrele

Europhysics Letters 77, 62001

Int. J. Mod. Phys. E16, 995



NOU: Pentru Z=92 – 118 am obtinut curbe universale diferite pentru nuclee p-p, i-p, p-i, i-i.

In figura T este perioada de injumatatire in secunde iar P_s este penetrabilitatea barierei externe (pentru $R > R_t$). Majoritatea supragrelelor sunt nuclee neutrono-deficitare si se dezintegreaza prin emisie α. Curbele universale dezvoltate de noi (dreptele din figura) explica bine datele experimentale (punctele din figura) privind dezintegrarea α a nucleelor grele si supragrele si pot prezice ce durate de viata vor avea nucleele supragrele care vor fi produse in viitor.

Implicarea tinerilor cercetatori in proiect

Tineri cercetatori: drd. Bogdan Popovici
drd. Mihaela Raportaru

Cei doi doctoranzi au invatat teoria energiei macroscopice in model picatura de lichid. Aceasta teoria au folosit-o in calculul energiei macroscopice cu forte de tip Yukawa-plus-exponentiala. Energia macrosopica a fost apoi introdusa in calculul energiei totale (energie picatura de lichid + corectiile de paturi) pentru a obtine energia de deformare a sistemelor binare in configuratie tipica fuziunii nucleare.

Actiuni individuale:

Mihaela Raportaru: Calculul energiei electrostatice pentru picatura de lichid deformata sferoidal si pentru sistem de doi sferoizi intersectati.

Bogdan Popovici: Calculul energiei de suprafata nucleara Yukawa pentru configuratie sferoid si pentru configuratie binara de doi sferoizi intersectati.

Cele doua energii insumate dau energia Yukawa-plus-exponentiala macroscopica.

Rezultatele obtinute de cei doi doctoranzi au fost:

1. Publicate separat in : Revista ISI: *International Journal of Modern Physics E (2010)*, in print. Titlul: Charge density influence on macroscopic deformation energy. Autori: R. A. Gherghescu, D. N. Poenaru, W. Greiner, M Raportaru, B. Popovici
2. Folosite in publicarea altor articole din cadrul proiectului.

Financiar: Chiar in conditiile restrangerii fondurilor de catre UEFISCSU am reusit sa le platim celor doi tineri cate 0.5 din salariul pe cate 8 luni/an. Restul a fost asigurat de Centrul de Calcul si DFT. Am fi dorit sa avem fonduri pentru a-i trimite la o Scoala de Vara.

Directorul de proiect. Radu Alexandru Gherghescu

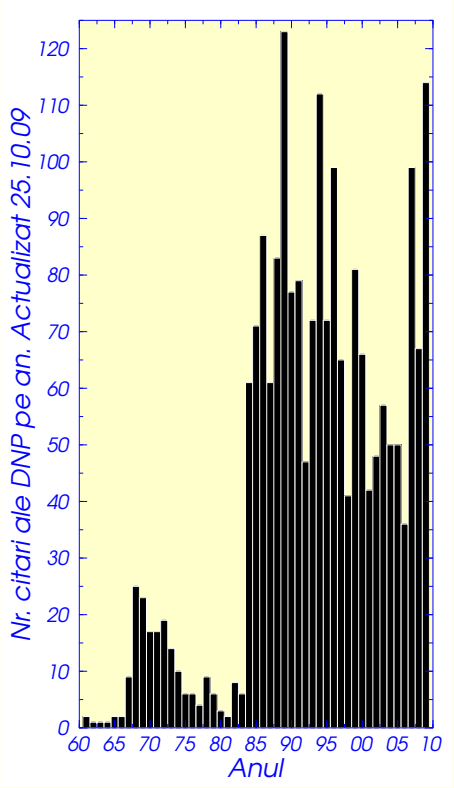
Dr. Radu Alexandru Gherghescu, CS1,
Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara Horia Hulubei (IFIN-HH) din Bucuresti,
Departamentul Fizica Teoretica

http://www.theory.nipne.ro/˜radu si
http://fias.uni-frankfurt.de/˜radu

In perioada de la inceperea contractului IDEI-124 (2007-2010) R. A. G. are 13 articole ISI.

Ocupa primul loc in clasificarea AdAstra a autorilor cu cel mai mare punctaj ISI in domeniul Fizicii Nucleare, pe autor in perioada 2002-2006.

DNP impreuna cu A. Sandulescu si W. Greiner sunt inclusi in *Encyclopaedia Britannica* pentru prezicerea *"heavy-ion radioactivity"*. Au fost confirmate experimental in centre din intreaga lume emisiile spontane de: ^{14}C, ^{20}O, ^{23}F, $^{22,24-26}$Ne, ^{28,30}Mg si $^{32-34}$Si din nuclee grele cu Z=87-96.



In 2009 distins de Deutsche Forschungsgemeinschaft (DFG) cu titlul de *"MERCATOR Gastprofessur"* la Frankfurt Institute for Advanced Studies, J. W. Goethe University, Frankfurt am Main, Germany. Este cea mai inalta distinctie acordata de DFG unor personalitati stiintifice din strainatate.

In anii 2007-2009 are 17 articole ISI, 8 prezentari invitate la conferinte internationale, 2 capitole de carte, 6 seminarii in strainatate. In 2007-2009 Oct. a fost citat de 280 ori (a se vedea figura). Conform criteriilor SPIRES (Stanford Linear Accelerator Center Database) are *6 publicatii faimoase (100-499 citari) si 3 publicatii bine cunoscute (50-99 citari).*
Are indice Hirsch = 23. Pagini de web: http://www.theory.nipne.ro/~poenaru si http://fias.uni-frankfurt.de/~poenaru

Rezumat - rezultate

Perioada: decembrie 2007 - octombrie 2009 (1 an, 10 luni)
Articole ISI : 12
Suma punctaj ISI = 25.027
Lectii invitate la conferinte internationale : 4

Identification data of the project:

Cod: 160

Director of the project : Radu A. Gherghescu

Project: IDEI-124

Title: *Synthesis and stability of superheavy nuclei*

http://proiecte.nipne.ro/pn2/index.php?id=42

Acronim: SINS

Starting time / finalized : 2007-10-01 / 2010-09-30

Financial value: 1000000 RON

Institution: Horia Hulubei National Institute for Physics and Nuclear Engineering

MEMBERS: Director of the project: Radu Alexandru GHERGHESCU

Experienced researcher: Dorin N. POENARU

Young reserachers (PhD students): Mihaela Raportaru

Bogdan Popovici

Radu.Gherghescu@nipne.ro

Project abstract

The main goal of the project is the development of a theoretical method able to characterize the nuclear fusion and fission phenomena and applicable to the synthesis and decay of superheavy nuclei. The topic is one of the hotest in nuclear research laboratories, both theoretical and experimental. Recently the newly synthesized superheavy nucleus Z=110 was named Darmstadtium (Ds), and new searches are underway for the extension of this nuclear region. In order to explain the stability of superheavy nuclei as well as to find the most favourable fusion channels, a specialized model must be able to describe the binary phenomena of synthesis and decay for these systems. The proposed project starts from the most complex two-center shell model, developed by the authors of this proposal. One aims to study the statics and dynamics of the synthesis and decay processes by applying a targeted binary macroscopic-microscopic method. The deformed two-center shell model shall generate the protonic and neutronic single particle levels necessary to calculate the shell and pairing corrections. The macroscopic part will be obtained by the liquid drop model within the Yukawa+exponential potentials. The dynamics of the process will ve settled by introducing the tensor of inertia within the binary cranking method, which shall be developed in this project using for the first time the two-center microscopic potential and the adapted BCS theory for the pairing effects. The multidimensional minimization of the action integral will provide the optimal fusion and fission trajectory for all possible target-projectile pairs towards the synthesis of a given superheavy nucleus. The algorithm will be repeated for a large range of atomic numbers between Z=108 and 130. The calculated pairs which will provide the largest penetrability values shall be suggested to experimentalists as the best synthesis reaction channels.

Objectives and activities and their degree of fulfilement

2007

Objective: 1. Macroscopic deformation energy for binary fusion shapes (2007-02-15).

Activities:

1.1 Calculation of the Coulomb energy for 2 intersected spheroids.

1.2 The Yukawa energy and total energy for fusion-like shapes.

Degree of fulfilement: integral.

2008

Objective:

1. Proton and neutron level scheme for fusion-like shapes

Activities:

1.1 The calculation of the single-particle proton and neutron levels.

1.2 Independent variation of spheroidal deformation in the overlapping region.

Degree of fulfilement: integral.

Objective:

2. Charge density variation within the intersected target-projectile configuration.

Activities:

2.1 Variation of the proton number within the light spheroid and calculation of the Coulomb energy.

2.2 Calculation of the single-particle levels for a given deformation.

Degree of fulfilement: integral.

Objectives and activities and their degree of fulfilement

Objective:
3. Total deformation energy for fusion-like shapes.
Activities:
3.1 Calculation of the proton and neutron shell corrections.
3.2 Calculation of the pairing energy.
3.3 Calculation of the total deformation energy.
Degree of fulfilement: integral.
2009
Objective:
1. Inertia tensor.
Activities:
1.1 The calculation of the Hamiltonian matrix elements as a function of the deformation variables
1.2 Calculation of the mass tensor components
Degree of fulfilement: integral.
Objective:
2. Minimization of the action integral.
Activities:
2.1 Calculation of the action integral within the space of deformation.
2.2 Numerical minimization within the multidimensional grid of deformation of the action integral.
Degree of fulfilement: integral.

Objectives and activities and their degree of fulfilement

Objective:

3. Penetrabilities and fusion cross sections in the synthesis of superheavy nuclei.

Activities:

3.1 Calculation of WKB penetrabilities

3.2 Calculation of cross section

Degree of fulfilement: integral

Performance indicators fulfilement between dec. 2007–apr.2010 – ISI-articles:

1. R. A. Gherghescu, D. N. Poenaru, W. Greiner, M. Raportaru, B. Popovici, *Charge density influence on macroscopic deformation energy*
   International Journal of Modern Physics E, (2010) in print. Factor ISI= 0.492
   http://www.worldscinet.com/ijmpe/
2. R. A. Gherghescu, D. N. Poenaru, A. Solovyov, W. Greiner, *Hemispheroidal atomic clusters on planar surfaces*
   Physica E 42, 1555-1562 (2010). Factor ISI=1.23
   http://www.elsevier.com/locate/physe.
3. R. A. Gherghescu and N. Carjan, *Two and three fragment emission from Z=120 isotopes*
   Journal of Physics G36, 025106 (2009). Factor ISI: 5.270
   http://iopscience.iop.org/0954-3899/
4. D. N. Poenaru, R. A. Gherghescu and W. Greiner, *Special properties of* ^{264}*Fm*
   Journal of Physics G, 125101 (2009), Factor ISI: 5.270
   http://iopscience.iop.org/0954-3899/
5. D. N. Poenaru and W. Greiner, *Extension of superasymmetric fission theory*
   Nuclear Physics A 834, 163-166 (2009) , Factor ISI: 1.959
   http://elsevier.com/locate/nuclphysa
6. R. A. Gherghescu, D. N. Poenaru and W. Greiner, *Proton gap due to the necking potential*
   Physical Review C78, 024604 (2008). Factor ISI: 3.124
   http://prc.aps.org/

Performance indicators fulfilement between dec. 2007–apr.2010 – ISI-articles:

7. R. A. Gherghescu, D. N. Poenaru and N. Carjan, *Neck influence on fission paths*
Physical Review C77, 044607 (2008). Factor ISI: 3.124
http://prc.aps.org/
8. R. A. Gherghescu, D. N. Poenaru and W. Greiner, *Binary and ternary emission from superheavy nuclei*
International J. of Modern Physics E17, 2221 (2008), Factor ISI: 0.492
http://www.worldscinet.com/ijmpe/
9. D. N. Poenaru and W. Greiner, *Cluster radioactivity - past, present and future*
International Journal of Modern Physics E17, 2255 (2008). Factor ISI: 0.492
http://www.worldscinet.com/ijmpe/
10. R. A. Gherghescu, D. N. Poenaru, A. Solovyov and W. Greiner, *Deformed shell closures*
International Journal of Modern Physics B22, 4917 (2008), Factor ISI: 0.684
http://www.worldscinet.com/ijmpb/
11. D. N. Poenaru, R. A. Gherghescu, N. Carjan, *Alpha-decay lifetimes semiempirical relationship including shell effects*,
Europhysics Letters 77 (2007) 62001. Factor ISI 2007: 2.206
http://epljournal.edpsciences.org/
12. D. N. Poenaru, R. A. Gherghescu, I. H. Plonski, W. Greiner, Int. J. Mod. Phys. E 16 (2007) 995-1007. Factor ISI: 0.684 http://www.worldscinet.com/ijmpe/

Invited lectures at international conferences

1. R. A. Gherghescu, D. N. Poenaru, *Neck influence on fission paths*. Lectie invitata, in Exotic Nuclei and Nuclear/Particle Astrophysics (II), (Proc. Carpathian Summer School of Physics, Sinaia, Romania, 2007) Eds. L. Trache and S. Stoica (American Institute of Physics (AIP) Conference Proceedings No. 972, Melville, NY, 2008) pp. 455-459.
2. D. N. Poenaru, *Shell corrections stabilizing superheavy nuclei and semi-spheroidal atomic clusters*. Invited talk. Published in Exotic Nuclei and Nuclear/Particle Astrophysics (II), (Proc. Carpathian Summer School of Physics, Sinaia, Romania, 2007) American Institute of Physics (AIP) Conference Proceedings No. 972, Melville, NY, 2008, pp. 165-173, Eds. L. Trache and S. Stoica, ISBN 978-0-7354-0490-8.
3. D. N. Poenaru and W. Greiner, *Fission approach to alpha-decay of superheavy nuclei*, Invited talk, Published in Fission and Properties of Neutron-Rich Nuclei (Proc. Fourth International Conference, Sanibel Island, FL, USA, 2007) World Scientific, Singapore, 2008, pp. 321-328, Eds. J. H. Hamilton, A. V. Ramayya, H. K. Carter, ISBN 978-981-283-342-6.
4. D. N. Poenaru, W. Greiner, *Extension of superasymmetric fission theory from cluster decay to nanophysics*, Invited talk, The 10th International Conference on Nucleus-Nucleus Collisions, Beijing, China, 16-21 August, 2009, to be published.

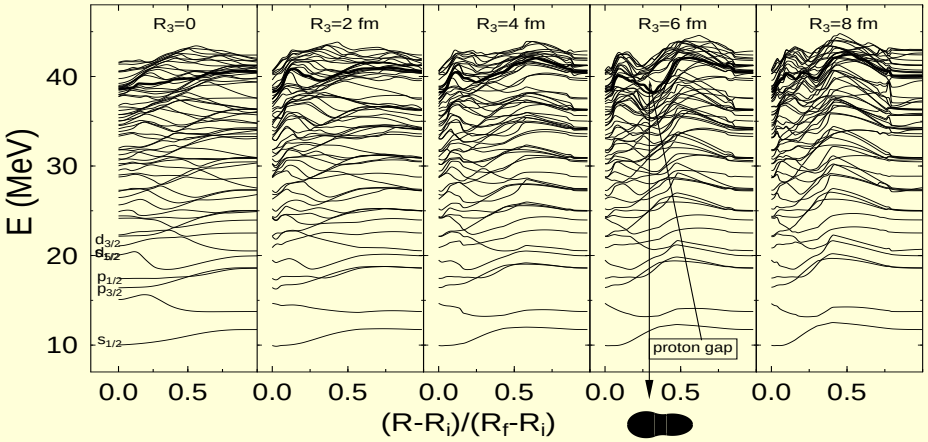
Theoretical grounds of the project IDEI-124

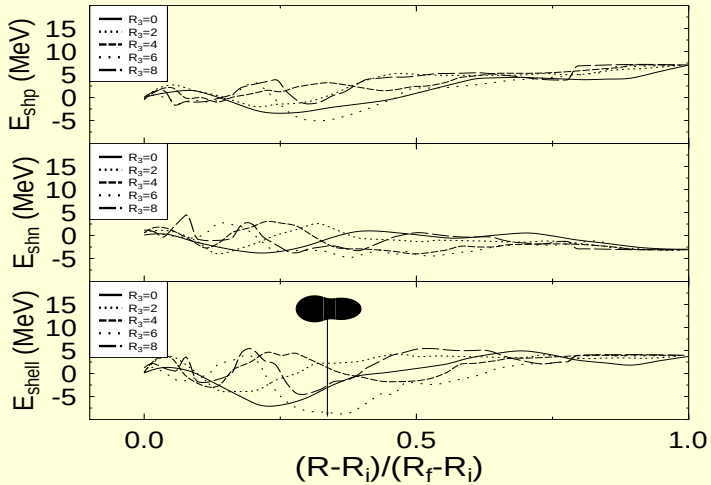
The BINARY macroscopic-microscopic method has been developed within the project IDEI-124. The corresponding calculation model for the energy allows the transition from a single quantum system towards two independent potential wells (fission) as well as the transition from two independent (target-projectile) systems towards a single one composed by the overlapping of the initial two potential wells (fusion).

The method uses the deformed two-center shell model, developed by the authors of this project. The model is based on the partial overlapping of two Nilsson potentials and is the only one able to describe the influence of two fragments within the binary configuration of fusion and fission.

New, original results, corresponding to the proposed objectives

2008 - Objective 1, 2:
Proton and neutron schemes
for fusion and fission
Phys. Rev. C78, 024604 (2008)
Int. J. Mod. Phys. B22, 4917 (2008)



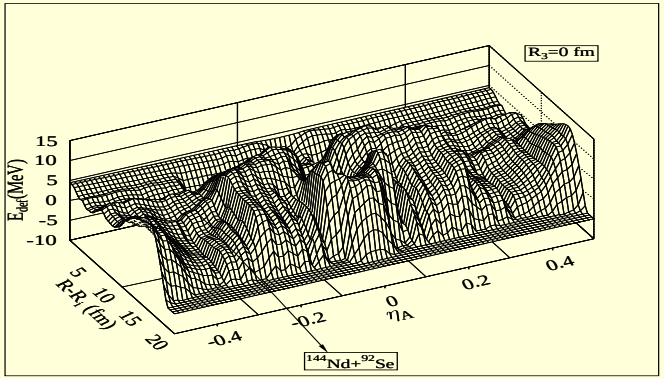


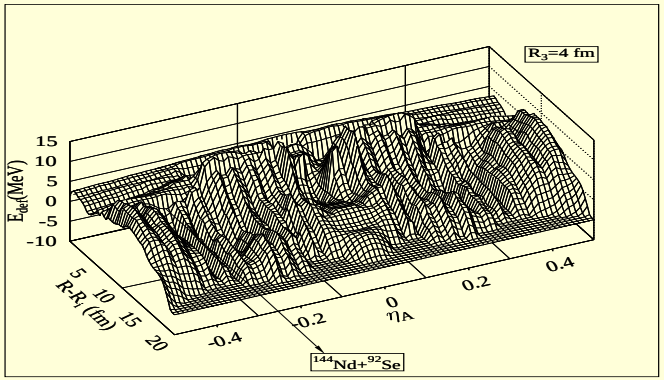
Proton level schemes for different neck parameters R_3
Proton, neutron and total shell correction variation,
with the reduced distance between centers
NEW: Proton gap due to the necking shell corrections,
generating the stability of an isomeric fission state.

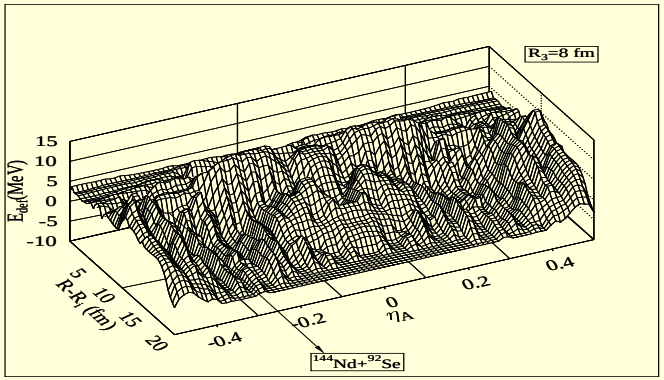
New, original results, corresponding to the proposed objectives

2007 - Objective:
Macroscopic deformation energy for
binary shapes

2008 - Objectiv 3:
Total deformation energy for
binary configurations
Phys. Rev. C77, 044607 (2008)







Potential energy surfaces calculated
from the minimization of the action integral.
NEW: Channel ^{144}Nd+^{92}Se,
experimenatlly found in fission of ^{236}Pu
at Geel (Belgium) and Strasbourg (France)
but theoretically unexplained until now.

New, original results, corresponding to the proposed objectives

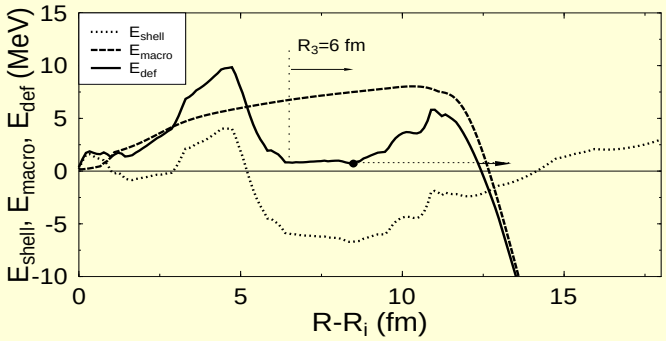
2009 - Objectives 2, 3:

Calculation of the action integral for fission

Multidimensional minimization and calculation of penetrabilities.

Phys. Rev. C77, 044607 (2008)

J.Phys. G 36, 125101 (2009)

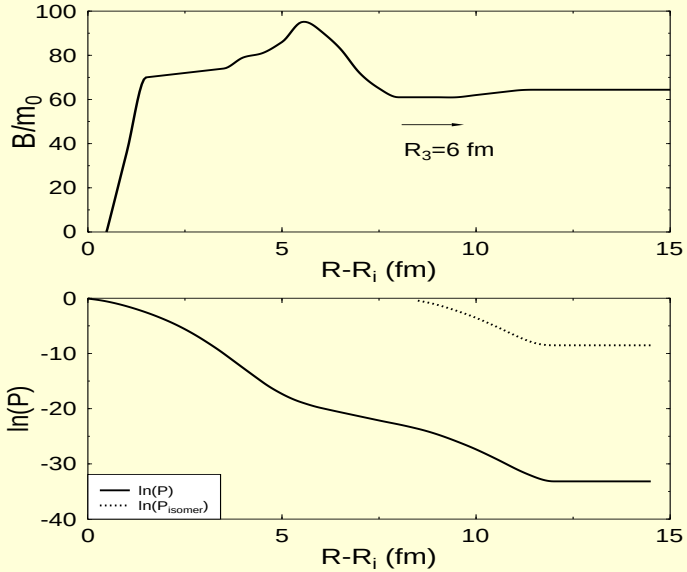


Total deformation energy, shell corrections and LDM.

Inertia tensor variation along the fission path.

WKB penetrabilities.

NEW: Neck parameter R_3 influence upon the dynamics (WKB) in binary quantum model.



New, original results, corresponding to the proposed objectives

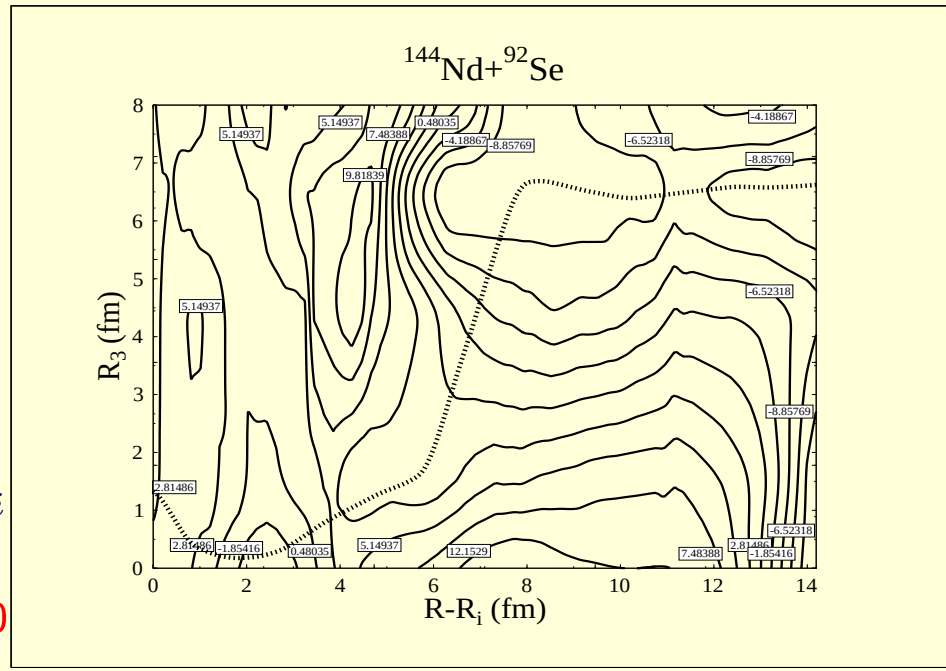
2009 - Obiectiv 2, 3:

Minimization of the action integral within the multidimensional space of deformation.

Calculation of the dynamic fusion and fission trajectory for heavy and superheavy nuclei.

J.Phys. G 36, 125101 (2009)

J.Phys. G 36, 025106 (2009)



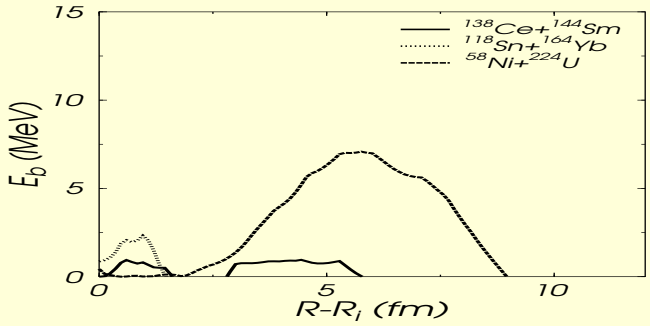
Dynamic trajectory of the fission channel as function of the neck radius R_3 and distance between centers $R - R_i$

Variation of the penetrability within WKB

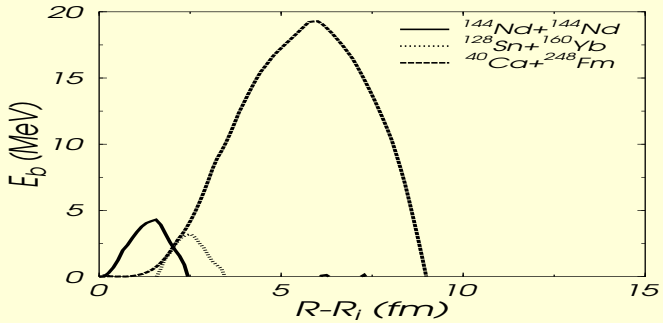
NEW: Exit from the barrier does not take place at R_3=0

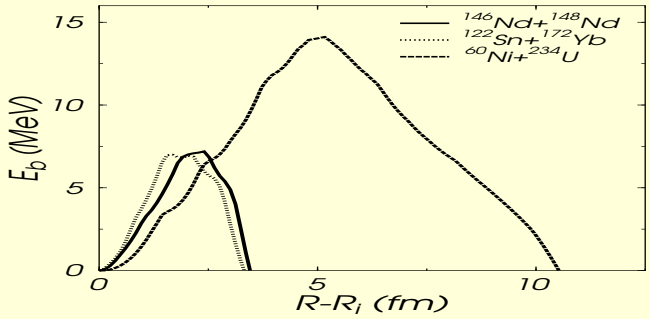
New, original results, corresponding to the proposed objectives

2009 - Obiectiv 2, 3:
Fusion and fission barriers for heavy and superheavy nuclei.
J.Phys. G 36, 125101 (2009)
J.Phys. G 36, 025106 (2009)

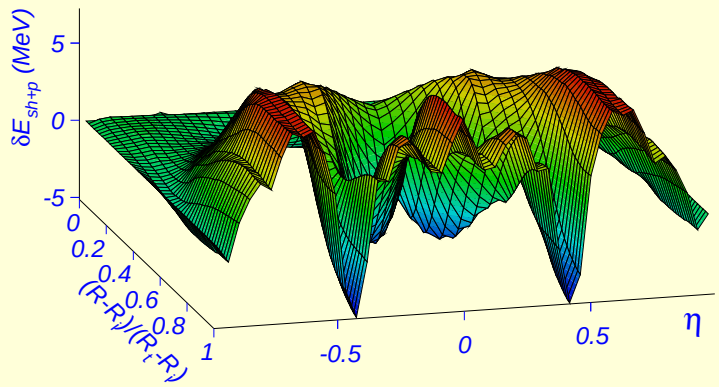


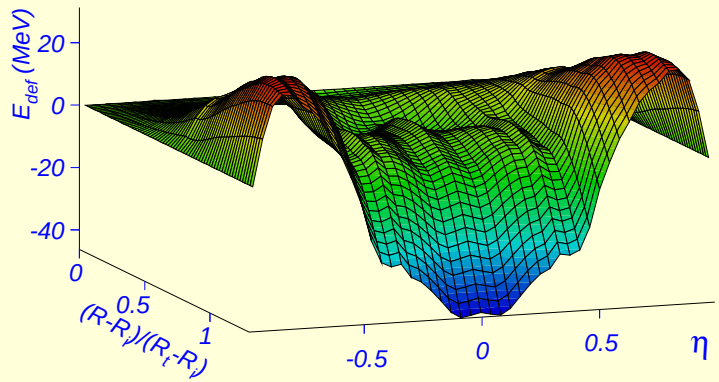
Fission barriers for $^{282,288,294}120$ corresponding to the 3 most favored decay channels.
NEW: The Sn-channel is favoured against the symmetric one due to shell effects.





Cold valleys on the potential energy surfaces





Potential energy surfaces for ^{294}118. Upper plot: shell and pairing corrections within our deformed two-center shell model.

Lower plot: total deformation energy. Mass asymmetry $\eta = (A_1 - A_2)/A$.

If the fusion reaction takes place along the cold valley corresponding to a double-magic target or neighbouring one ($\eta \simeq 0.41$ in figure), the nucleus has a minimum excitation energy and after neutron evaporation, a superheavy nucleus is identified by α emission. NEW: We obtained the Pb valley with our two-center shell model.

The importance of the project: New superheavy elements at GSI-Darmstadt (Gottfried Münzenberg, Sigurd Hofmann et al.)

107 Bh Bohrium (^{54}Cr + ^{209}Bi$_{126}$ $\longrightarrow$ ^{263}Bh*)

108 Hs Hassium (^{58}Fe + ^{208}Pb$\longrightarrow$ ^{266}Hs*)

109 Mt Meitnerium (^{58}Fe + ^{209}Bi$\longrightarrow$ ^{267}Mt*)

110 Ds Darmstadtium (^{62}Ni + ^{208}Pb$\longrightarrow$ ^{270}Ds*)

111 Rg Roentgenium (^{64}Ni + ^{209}Bi$\longrightarrow$ ^{273}Rg*)

112 Cn Copernicum sau Copernicium (IUPAC will decide in 2010) (^{70}Zn + ^{208}Pb$\longrightarrow$ ^{278}Cn*)

and 113 at RIKEN (Kosuke Morita et al.)

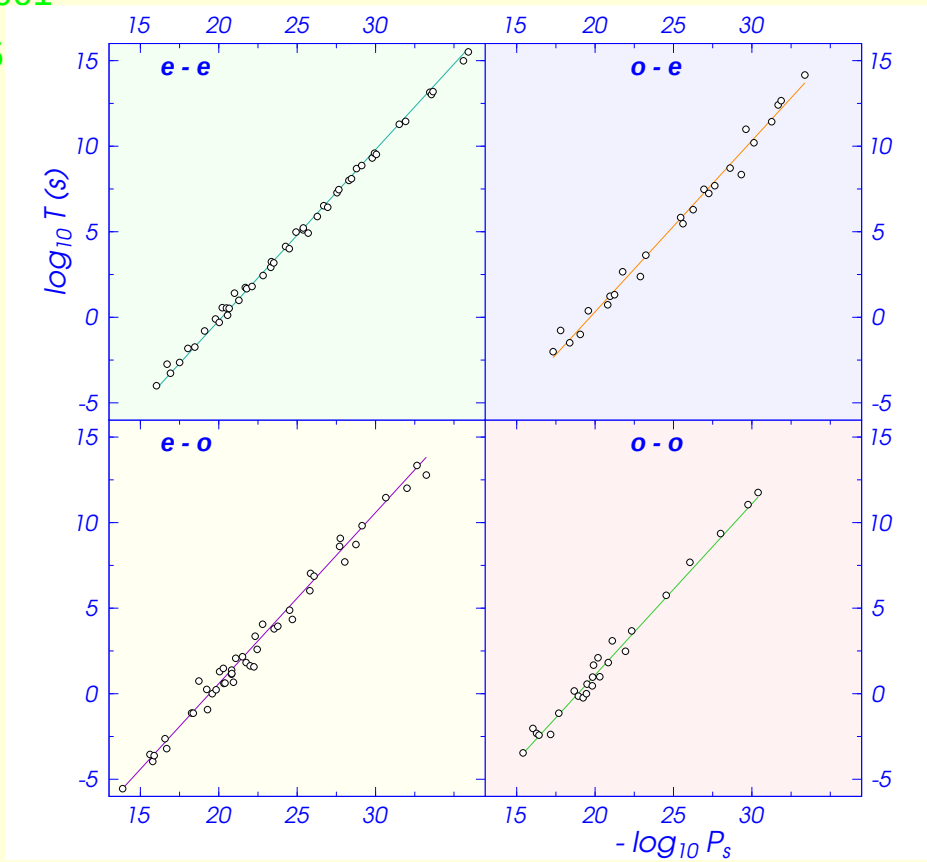
113 (^{70}Zn + ^{209}Bi$\longrightarrow$ ^{279}113*)

have been produced with ^{208}Pb ($Z = 82$, $N = 126$) or ^{209}Bi ($Z = 83$, $N = 126$).

α lifetimes for heavy and superheavy nuclei

Europhysics Letters 77, 62001

Int. J. Mod. Phys. E16, 995



NEW: For Z=92 – 118 we obtained different universal curves for e-e, o-e, e-o and o-o nuclei p-i, i-i.

T is the halflife in seconds, P_s is the penetrability of the external barrier (for $R > R_t$). The majority of the superheavies are neutron-deficient and decay by α emission. Our universal curves (straight lines in the figure) explain the experimental data (dots) for α decay of heavy and superheavy and can predict the lifetimes of future superheavy nuclei.

Involvement of young researchers in the project

Young researchers: drd. Bogdan Popovici

drd. Mihaela Raportaru The two PhD students learned the theory of macroscopic energy within the LDM. They used this theory to calculate the macroscopic energy with Yukawa+exponential forces. The macrosopic energy has been introduced in the calculation of the total energy (liquid drop + shell corrections) to obtain the deformation energy of binary systems for fusion configurations.

Individual actions:

Mihaela Raportaru: Calculation of the electrostatic energy for deformed liquid drop spheroid and for two intersected spheroids.

Bogdan Popovici: Calculation of the Yukawa energy for spheroid and for two intersected spheroids.

The sum of the two energies yield the macroscopic Yukawa-plus-exponential energy.

The results of the two students have been:

1. Published in ISI journal: *International Journal of Modern Physics E (2010)*, in print. Title: Charge density influence on macroscopic deformation energy. Authors: R. A. Gherghescu, D. N. Poenaru, W. Greiner, M Raportaru, B. Popovici

2. Used in the publication of other articles within the project.

Financial remark: Even within the restrain of fonds, we managed to pay the two young researchers 0.5 salary for 8 months per year. We would have liked to have fonds to send them at an Interantional Summer School.

Project director: Radu Alexandru Gherghescu

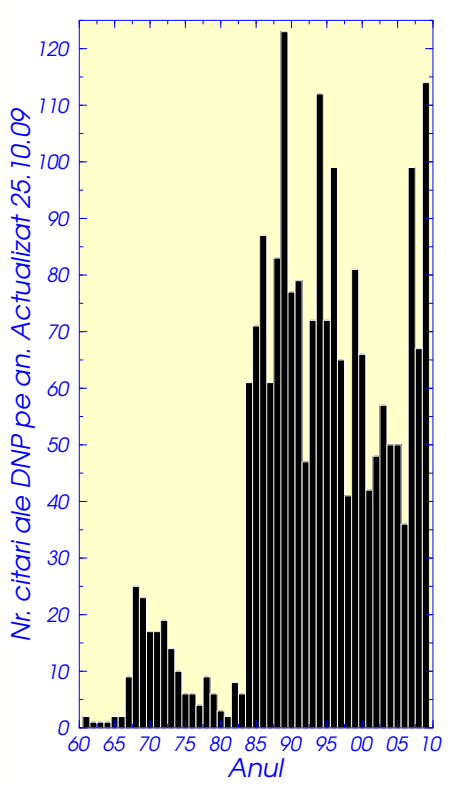
Dr. Radu Alexandru Gherghescu, CS1,
National Institute for Physics and Nuclear Engineering (NIPNE-HH), Bucharest-Magurele,
Department of Theoretical Physics.

http://www.theory.nipne.ro/˜radu and
http://fias.uni-frankfurt.de/˜radu

During the period of the contract IDEI-124 (2007-2010) R. A. G. has 13 ISI articles.

He is placed on first position within the AdAstra authors with the greatest ISI score in Nuclear Physics along 2002-2006.

DNP together with A. Sandulescu and W. Greiner are included in *Encyclopaedia Britannica* for the prediction of *"heavy-ion radioactivity"*. Experimental confirmation of their discovery: ^{14}C, ^{20}O, ^{23}F, $^{22,24-26}$Ne, ^{28,30}Mg si $^{32-34}$Si from heavy nuclei with Z=87-96.



In 2009 the Deutsche Forschungsgemeinschaft (DFG) distinguished prof. Poenaru with the *"MERCATOR Gastprofessur"* title at the Frankfurt Institute for Advanced Studies, J. W. Goethe University, Frankfurt am Main, Germany.

Between 2007-2009 he has 17 ISI-articles , 8 invited lectures, 2 book chapters, 6 invited seminars abroad. In 2007-2009 he has been cited 280 times. His Hirsch index = 23.
Web pages:
http://www.theory.nipne.ro/~poenaru
and
http://fias.uni-frankfurt.de/~poenaru

Conclusion - results

Period: december 2007 - december 2009 (2 years)
ISI Articles : 12
ISI-summed score = 25.027
Invited lectures : 4