

Theoretical nuclear activities in Belgium a short review

Pierre Capel

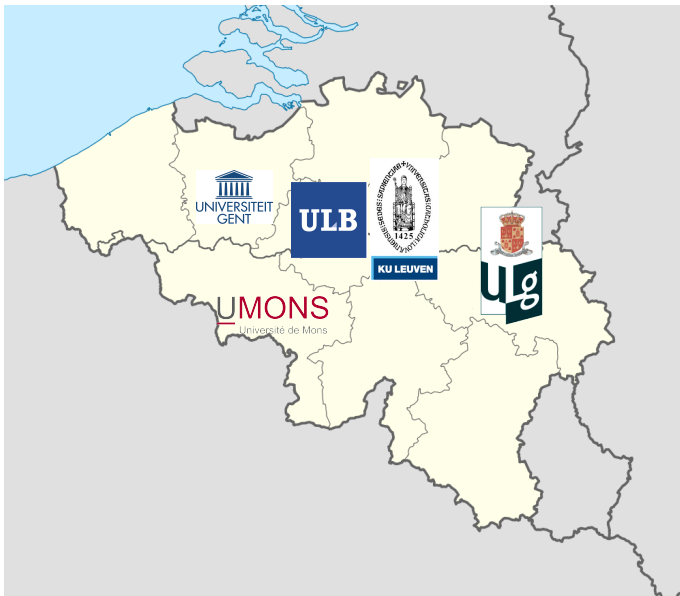


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DE BRUXELLES



15th Octobre 2015

Nuclear-Theory Groups in Belgium



- 1 Nuclear Structure
- 2 Nuclear Reactions
- 3 Nuclear Astrophysics
- 4 Neutrino-nucleus interaction
- 5 Hadron Structure
- 6 Summary

Nuclear Structure

- Medium and heavy nuclei :
 - Algebraic- and shell-model calculations : K. Heyde
 - Mean-field calculations : P.-H. Heenen
- Study of Short-Range Correlations in nuclei :
J. Ryckebusch



Nuclear Structure

- Medium and heavy nuclei :
 - Algebraic- and shell-model calculations : K. Heyde
Shape coexistence in nuclei and
emergence of collectivity from microscopic bases
 - Mean-field calculations : P.-H. Heenen
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Large-Scale Shell Model calculations

Recent calculations on Cd isotopes
that explain vibrational spectrum from LSSM

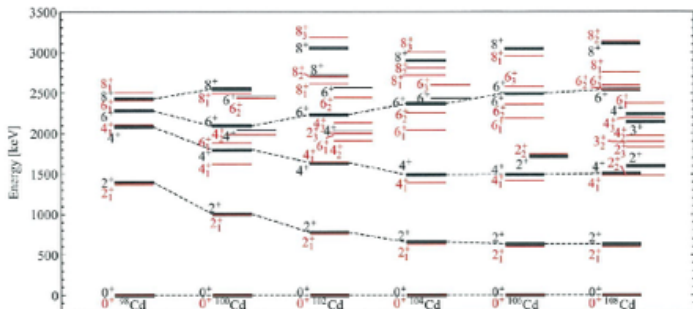


Figure 1. Experimental (black) and LSSM (red) energy spectra of the even-even light Cd isotopes.

[Blazhev, Heyde, Schmidt, CGS15]

Nuclear Structure

- Medium and heavy nuclei :

- ▶ Shell-model calculations : K. Heyde



- ▶ Mean-field calculations : P.-H. Heenen

The logo of ULB (Université Libre de Bruxelles), consisting of the letters "ULB" in white on a blue square background.

Solving Skyrme HF+BCS equations on 3D mesh,
beyond mean-field calculations (odd isotopes)

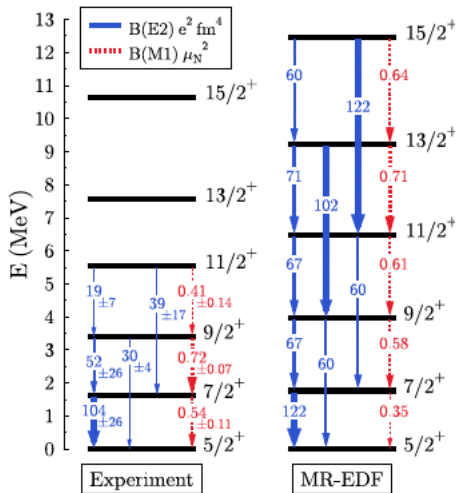
- Study of Short-Range Correlations in nuclei :

J. Ryckebusch



Beyond Mean-Field calculations

Recent calculations of ^{25}Mg beyond mean-field



[Bally, Avez, Bender, Heenen, PRL 113, 162501 (2014)]

Nuclear Structure

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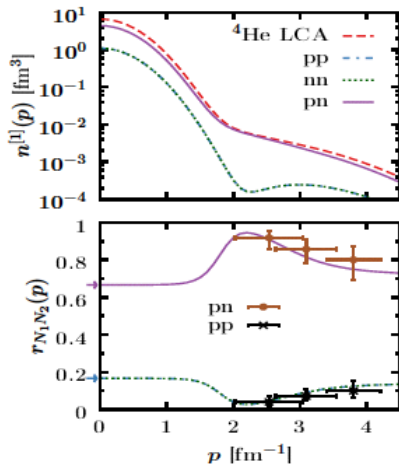


Analysis of SRC, their mass and isospin dependence and effects in $p(A, pNX)$ with unstable nuclei

Study of Short-Range Correlations

SRC effects in single-nucleon momentum distribution

Tensor force and p - n pairs are significant in high-momentum tail



[Ryckebusch, Vanhalst, Cosyn JPG 41, 055104 (2015)]

Nuclear Reactions

- Study of exotic nuclear structures : halos, shell inversion...

- CDCC calculations : P. Descouvemont **ULB**

- Eikonal models : D. Baye, P. Capel **ULB**

- Reactions of astrophysical interest :

- Cluster-model calculations : D. Baye, P. Descouvemont **ULB**

- Inverse problem : D. Baye, J.-M. Sparenberg **ULB**

Nuclear Reactions

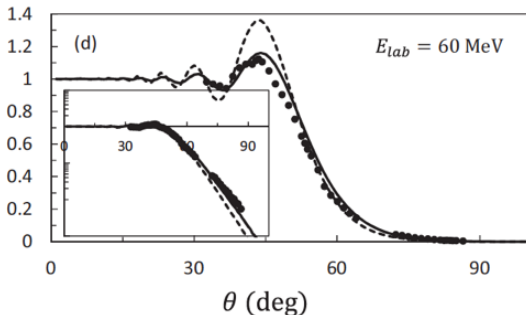
- Study of exotic nuclear structures : halos, shell inversion...
 - ▶ CDCC calculations : P. Descouvemont **ULB**
Including microscopic description of projectile,
4-body model of reaction (3-b projectile)
 - ▶ Eikonal models : D. Baye, P. Capel **ULB**
- Reactions of astrophysical interest :
Cluster-model calculations : D. Baye, P. Descouvemont **ULB**
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4-body CDCC

Development of a 4-body CDCC model

${}^9\text{Be}(\equiv \alpha + \alpha + n) + \text{Pb}$ @ 60 MeV

Reproduces elastic scattering, breakup and fusion



[Descouvemont, Druet, Canto, Hussein, PRC 91, 024606 (2015)]

Nuclear Reactions

- Study of exotic nuclear structures : halos, shell inversion. . .

- ▶ CDCC calculations : P. Descouvemont **ULB**

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Extension of the eikonal approximation to low energy,
heavy target and 3-body projectiles

- Reactions of astrophysical interest :

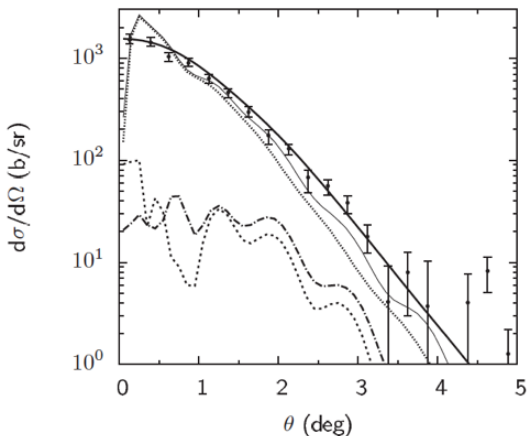
Cluster-model calculations : D. Baye, P. Descouvemont **ULB**

- Inverse problem : D. Baye, J.-M. Sparenberg **ULB**

Three-body breakup at the eikonal approximation

Eikonal model corrected for Coulomb extended for 3-b projectiles

$^{11}\text{Li}(\equiv {}^9\text{Li} + n + n) + \text{Pb} @ 70\text{A MeV}$



[Pinilla, Descouvemont, Baye, PRC 85, 054610 (2012)]

Nuclear Reactions

- Study of exotic nuclear structures : halos, shell inversion...

- ▶ CDCC calculations : P. Descouvemont **ULB**

- ▶ Eikonal models : D. Baye, P. Capel, P. Descouvemont **ULB**

- Low-energy reactions :

Cluster-model calculations : D. Baye, P. Descouvemont **ULB**

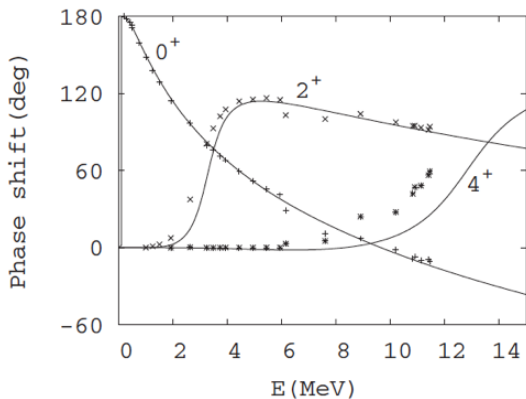
For long, state-of-the-art microscopic cluster models for astrophysical applications

Recently : extension of the model to realistic N - N forces for elastic scattering and Bremsstrahlung

- Inverse problem : D. Baye, J.-M. Sparenberg **ULB**

Microscopic cluster model

Microscopic description of α - α elastic scattering



[Dohet-Eraly, Baye, PRC 84, 014604 (2011)]

Nuclear Reactions

- Study of exotic nuclear structures : halos, shell inversion. . .

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- Low-energy reactions :

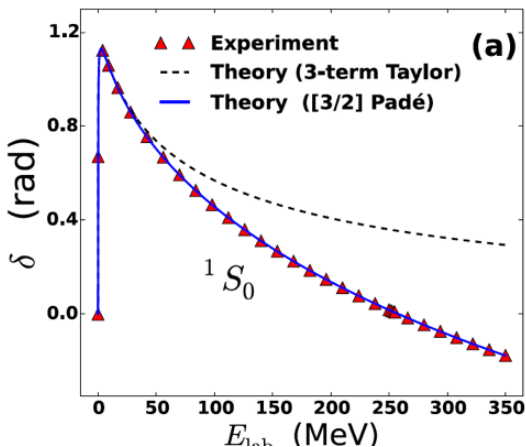
- Cluster-model calculations : D. Baye, P. Descouvemont **ULB**

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- Use supersymmetric technique to deduce nuclear interaction from phaseshifts

Inverting n - p interaction

Padé expansion of effective-range functions leads to an elegant V_{np}



[Midya, Evrard, Abramowicz, Ramirez Suarez, Sparenberg, PRC 91, 054004 (2011)]

Nuclear Astrophysics

- Low-energy reactions :

Cluster-model calculations : D. Baye, P. Descouvemont

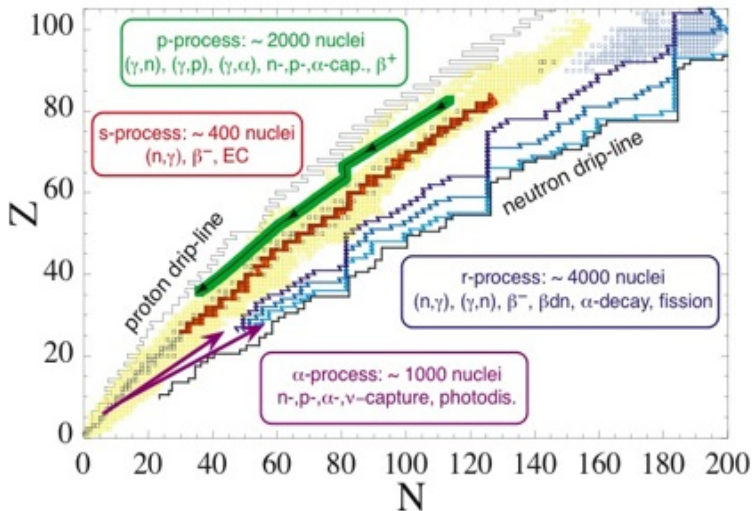
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- Nuclear-astrophysics group : S. Gorielly, N. Chamel

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- ▶ Mean-field calculations to obtain nuclear masses
application to EoS
- ▶ QRPA calculations for EM and GT strengths
- ▶ Reaction-rate calculations

Astrophysical application of nuclear physics



[S. Goriely to be published in EPJA]

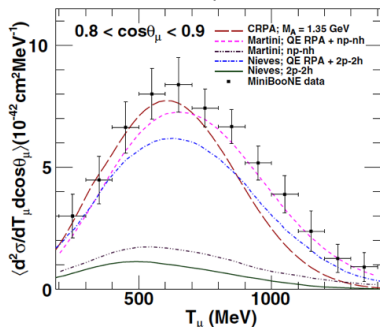
Neutrino Physics

Theoretical prediction for ν -nucleus interaction

N. Jachowicz, J. Ryckebusch



- Calculation of $\bar{\nu}_\mu + {}^{12}\text{C} \rightarrow \mu^+ + X$




[Pandey, Jachowicz, Ryckebusch, Van Cuyck, Cosyn, PRC 89 024601 (2014)]


- Influence of low-energy nuclear excitation induced by neutrinos
- Influence of two-nucleon effects (SRC)
- Neutrino-induced pion production

Hadron Structure


- Study of baryon structure through $p(\gamma, K^+)\Lambda$

J. Ryckebusch  UNIVERSITEIT
GENT

- Study of quark-gluon plasma

C. Semay  UMONS
Université de Mons

- Lattice QCD

J.-R. Cudell 

Summary

Large number of subjects from (very) low energy to hadron structure

The main groups, members of BriX are



J. Ryckebusch, N. Jachowicz, K. Heyde

2 post-docs, 6 PhD students

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P. Descouvemont, J.-M. Sparenberg, P. Capel, D. Baye,

P.-H. Heenen, 4 PhD students

ULB

S. Gorielly, N. Chamel

4 post-docs

There are strong interactions with (Belgian) experimental groups