Theory group of GANIL

Theory group of GANIL

- 4 permanents positions (3.5 full time equivalent)
    - 1 or 2 post-docs + 2 to 3 PhD students
- 4 different research topics, with collaborations all over the world
- 26 PhD students, 5 books and 568 research articles (94 with experimentalists)
- Various responsibilities (Talent, PICS/IEA, IRP, Academic or scientific committees…)

Nuclear open quantum systems

Nuclear open quantum systems

One permanent and (usually) one PhD student. Since 2000, two postdoctoral fellows: A. Dassie (current)

Creation of the France-U.S. Theory Institute for Physics with Exotic Nuclei (FUSTIPEN) for theoretical research on the physics of nuclei and dedicated to collaborative research between U.S. and French nuclear physicists

Creation of the international training program TALENT for graduate students and young researchers in cutting-edge nuclear theory for understanding nuclei and nuclear reactions

Creation of international initiative on “Many-body Open Quantum Systems: From Atomic Nuclei to Quantum Optics” with the series of programs at the ECT* Trento

A handbook on the shell model for nuclear open quantum systems, with exercises and computer codes provided, for advanced university courses in the theory of weakly bound or unbound nuclear and atomic systems

Scientific output: 2 books, editor of 3 books, over 220 articles in refereed journals including 7 monographs

Fellow of the American Physical Society with citation: *“For his seminal contributions to studies of open quantum systems, his formulation and implementation of the continuum shell model and Gamow Shell Model, and their use to describe weakly bound nuclear states and resonances”*

Organisation of over 40 international workshops and conferences.
In near future: organization of 2 weeks program at the INT-Seattle on “Quantum Physics of Stars”, and 3 weeks TALENT program at GANIL on “Physics of nuclear open quantum systems”

Why do we care about the continuum?

- r-process nucleosynthesis takes place far from the valley of β-stability

- Appearance of exotic correlations and clusterings: 2p, 2n, ^{2}H, ^{3}He, ^{3}H, ^{4}He,… near-threshold states in the vicinity of self-conjugate nuclei

- Nuclear states are *embedded in the scattering continuum*

- Couplings to various particle emission channels are crucial for the properties of near-threshold states

- Thresholds are branching points → nonanalytic behavior
  - Wigner threshold law for *elastic and total cross-sections*
    E.P. Wigner, Phys. Rev. 73, 1002 (1948)

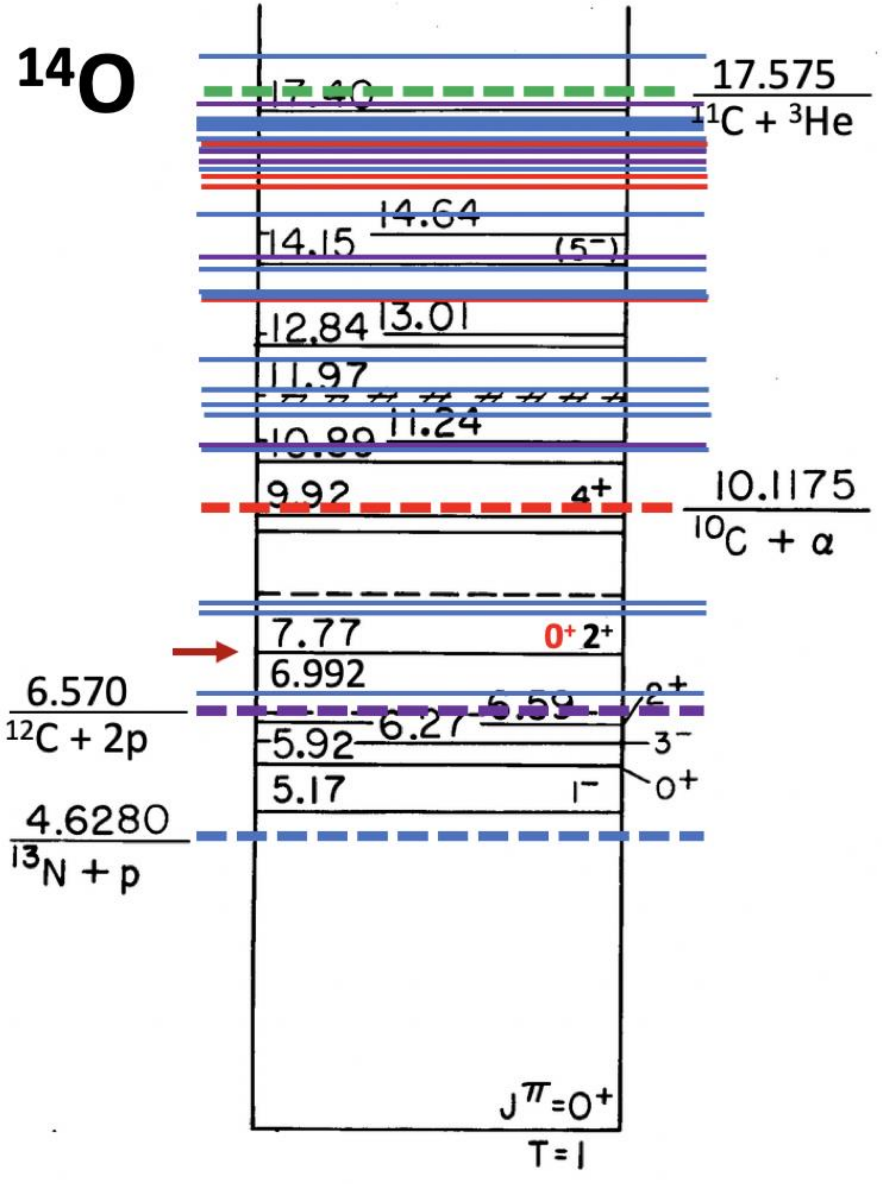
    and *spectroscopic factors*
    N. Michel, W. Nazarewicz., M. Ploszajczak, Phys. Rev. C(R) 75, 031301 (2007)

↓

Shell model for *open* quantum systems

- Shell model embedded in the continuum (SMEC)
  J. Okołowicz, M. Ploszajczak., I. Rotter, Physics Reports 374, 271 (2003)

- Gamow shell model (GSM)
  N. Michel et al, Phys. Rev. Lett 89, 042502 (2002)
  N. Michel, M.Płoszajczak, Lecture Notes in Physics, Vol. 983, (Springer Verlag, 2021)



NN interaction in different regimes of binding

GSM study

Dependence of V_{nn}/V_{pp} on $S_n - S_p$ asymmetry

ℓ_j	J^π	S_p[MeV]	S_n[MeV]	V_{nn}/V_{pp}
$p_{1/2}$	2^+	10	-1	0.39
		1	-1	0.58
$d_{5/2}$	2^+	10	-1	0.83
		1	-1	0.835
	4^+	10	-1	0.75
		1	-1	0.84

- Strong asymmetry of V_{nn} and V_{pp} *for large* $|S_n - S_p|$ *and low* ℓ_j
- If $S_n \ll S_p$, then $V_{pp} > V_{nn}$, i.e. protons in the neutron-rich environment interact stronger than neutrons

Dependence of spectroscopic factors on $S_n - S_p$ asymmetry

Spectroscopic factors for the knockout of a $p_{3/2}$ nucleon from the 3/2- g.s. of ^{9}C and ^{9}Li to the g.s. of ^{8}B, ^{8}He, ^{8}B, and ^{8}Li

Model	N_{cont}	$^9C \to {}^8C$ 14.22	$^9Li \to {}^8He$ 13.94	$^9C \to {}^8B$ 1.30	$^9Li \to {}^8Li$ 4.06
HO-SM	0	0.86	0.85	0.95	0.96
GSM-*ps*	3	0.67	0.67	0.98	0.98
GSM-*psd*	3	0.60	0.67	0.89	0.88
GSM-*psd*	4	0.48	0.65	0.89	0.88
GSM-psd_{res}	4	0.48	0.64	0.84	0.85

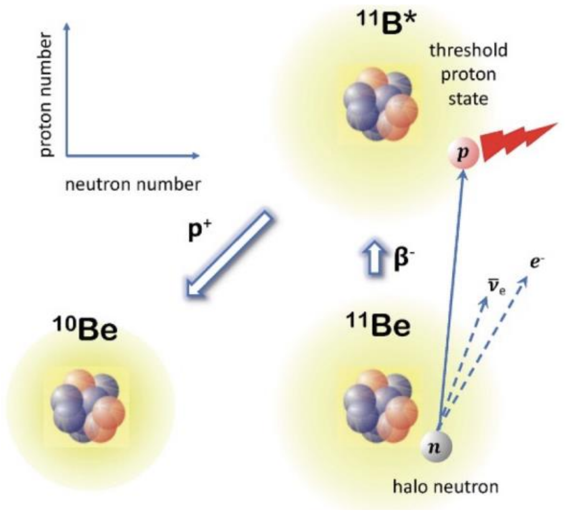
- If $S_n >> S_p$, then neutron spectroscopic factor is reduced with respect to proton spectroscopic factor, and vice versa if $S_p >> S_n$

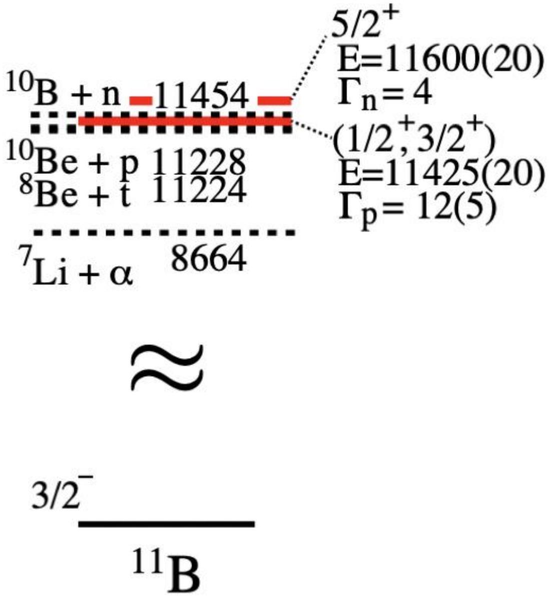
N. Michel, M.Płoszajczak,
«*Gamow Shell Model: The Unified Theory of Nuclear Structure and Reactions* »
Lecture Notes in Physics, Vol. 983, (Springer Verlag, 2021)
J. Wylie, J. Okolowicz et al, Phys. Rev. C 104, L061301 (2021)

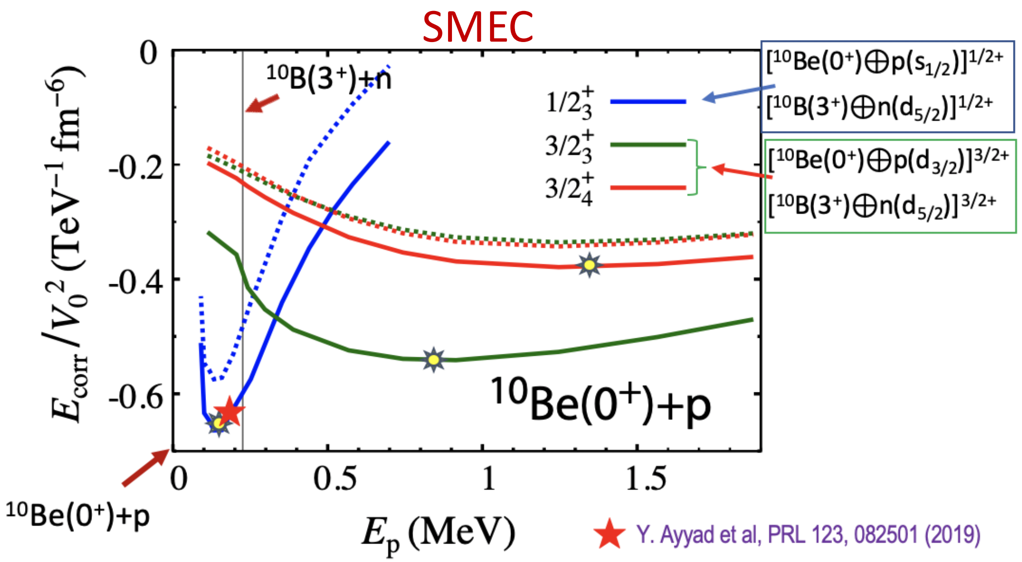
Challenge for experimental studies!

Near-threshold collectivization - β-delayed proton emission

Example: proton-emitting resonance in ^{11}Be







- SMEC explains β-delayed p emission from ^{11}Be
  J. Okolowicz, W. Nazarewicz, M. Ploszajczak, Phys. Rev. Lett 124, 042502 (2020)
- Later experiments confirm near-threshold resonance in ^{11}Be

  Excitation function of elastic scattering ^{10}Be+p
  Y. Ayyad et al (MSU Coll.), (2022)

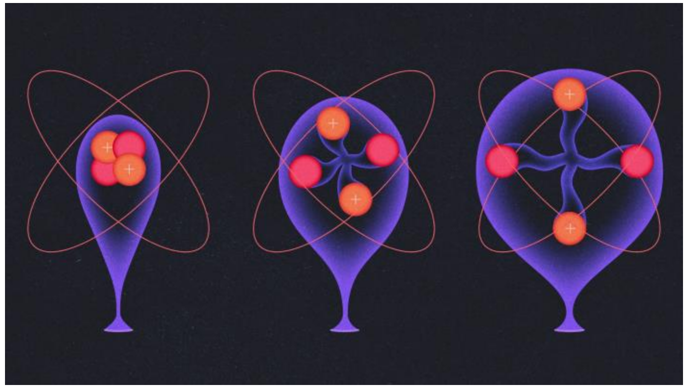
  Transfer reaction ^{10}Be(d,n)^{11}B* ⟶ ^{10}Be+p
  E. Lopez-Saavedra et al (FSU Coll.), (2022)

Puzzle of 0^+ resonance of the α particle

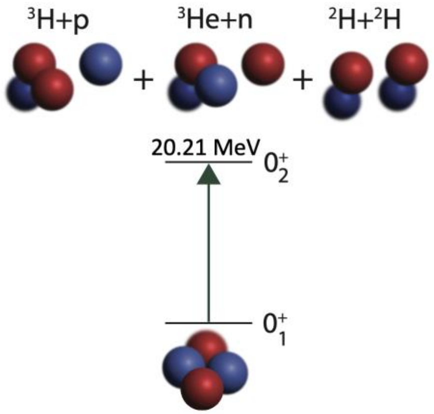
Measurement of the α-particle monopole transition form factor

"… we observe that modern nuclear forces, including those derived within chiral effective field theory that are well tested on a variety of observables, fail to reproduce the excitation of the α particle…" S. Kegel et al., PRL 130, 152502 (2023)

Is the first excited state of ^{4}He inflating like a balloon?



or it is the cluster state?



- Gamow shell model explains the monopole transition formfactor using N^{3}LO chiral interaction
- Strong continuum coupling between [t + p], [^{3}He + n], [d + d] reaction channels
- First excited state of ^{4}He is NOT a breathing model but an aligned state dominated by the [t + p] channel
- Monopole form factor is fairly sensitive to interactions, threshold positions and resonance energy, hence is not an ideal quantity when it comes to constraining nuclear interactions

N. Michel, W. Nazarewicz, M. Ploszajczak, Phys. Rev. Lett. 131, 242502 (2023); ibid 109, 059902(E) (2024)

Experiment envisionned at GANIL

Astrophysical relevance of near-threshold states for capture reactions of nucleosynthesis

Threshold physics is key in astrophysical reactions

- Resonances can affect S-factor
- Possible non-trivial impact in stellar cycles

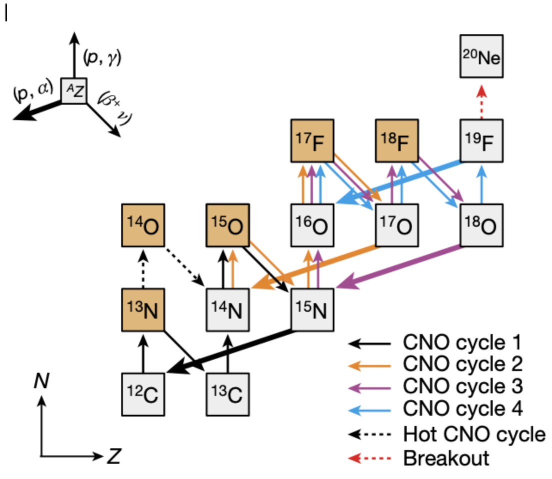
- *Ab initio* GSM studies of resonances in ^{4}He, ^{5}He and ^{5}Li
  → Crucial role in thermonuclear fusion reactions
  with D. **Cardona**, N. Michel (2025)

- GSM radiative capture reactions involved in Big Bang nucleosynthesis: ^{6}Li(n,γ), ^{6}Li(p,γ), ^{8}Li(n,γ), ^{8}B(p,γ), …
  with G.X. Dong and X.B. Wang (2017 – 2024)

- Radiative capture reaction rates at extremely low excitation energies: ^{14}N(p,γ), ^{19}F(p,γ), … with G.X. Dong and X.B. Wang (2024)

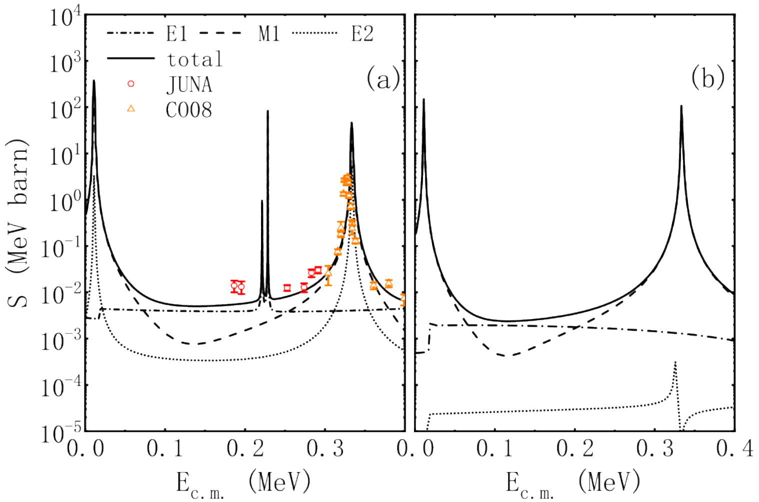
- Near-threshold resonances in ^{11}C and ^{10}B(p,α) a neutronic reaction J. Okolowicz, M. Ploszajczak, W. Nazarewicz, Phys. Rev C L021305 (2023), ibid. 109, 059902(E) (2024); with A. Dassie, N. Michel (2025)

- GSM studies of ^{3}H induced reactions in Big Bang nucleosynthesis J.P. **Linares Fernandez**, et al, Phys. Rev. C 108, 044616 (2023);



Liyong Zhang et al., Nature 610, 656 (2022)

GSM-CC



G.X. Dong et al, Phys. Rev. C 110, L061601 (2024)

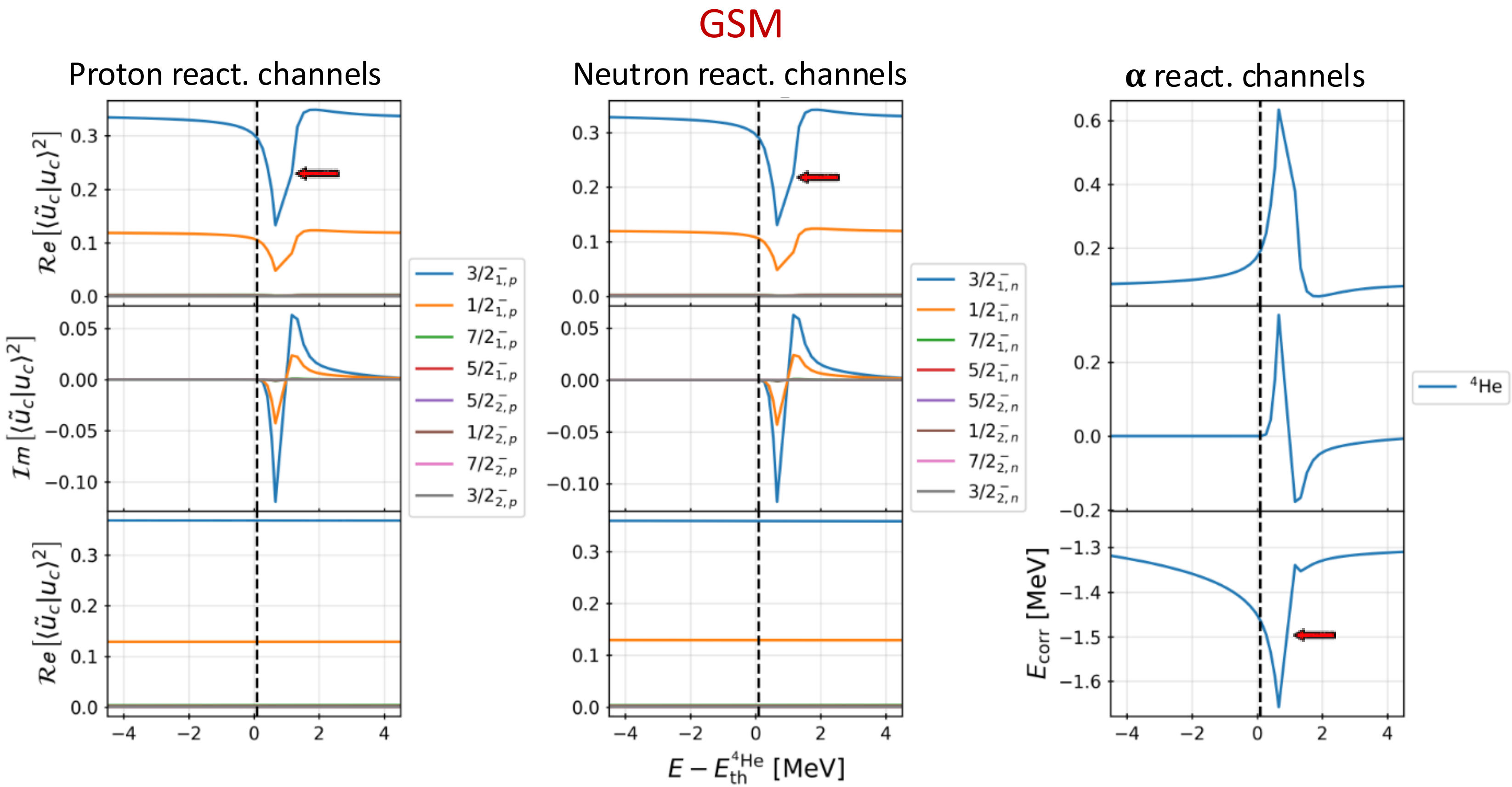
Does ^{19}F(p,γ)^{20}Ne breakout reaction from the CNO cycle overcomes ^{19}F(p,α)^{16}O back-process reaction cross section becoming a source of the Ca abondance in the first generation stars?

- GSM-CC reaction rates are significantly larger than in NACRE and comparable with JUNA data

- ^{19}F(p,α)^{16}O back-process reaction should be remeasued to verify the hypothesis of breaking from hot-CNO cycle

Mimicry mechanism of near-threshold clusterization

^{8}Be



- The resonance changes its structure as a result of the alignment (*mimicry*) with the nearby reaction channel (*changing environment*)

- Near-threshold clustering is the *emergent phenomenon* in shell model for *open* quantum systems

J.P. **Linares Fernandez**, et al, Phys. Rev. C 108, 044616 (2023)

Recent projects in collaboration with experimentalists

- Narrow resonances in the unbound nucleus ^{15}F V. Girard-Alcindor, et al, Phys. Rev. C 105, L051301 (2022)
- Resonance spectroscopy of ^{33}K with A. Dassie, B. Fernandez-Dominguez, et al (2025)
- The unbound ν1d3/2 orbital in ^{17}C : survival of the N=16 shell gap with J. Lois Fuentes, B. Fernandez-Dominguez, et al (2025)
- β-delayed neutron spectroscopy of ^{24}O with S. Neupane, N. Ktamura et al, Phys. Rev. C 110, 034323 (2024)
- The decay of the 21.47-MeV 'stretched' M4 resonance in ^{13}C N. Cieplinska-Orynczak, Y. Jaganathen et al, Phys. Lett. B 834, 137938 (2022)
- Is the spectroscopic factor constant – study of ^{7}Li near ^{4}He + ^{3}H decay threshold with L. Dienis, J.P. Linares-Fernandez, F. de Oliveira et al (2025)
- Decay of near-threshold state in ^{17}B by n, 2n, and γ with A. Volya, S.M. Wang, O. Sorlin (2025)
- Study of the structure of ^{4}He in the reaction $^{4}He(n,n')^{4}He^{*}$ using neutron beams at NSF with A. Chbihi, N. Michel (2025)
- Deviations from quadratic isospin multiplet mass equation due to the continuum coupling with R. Charity, L. Sobotka, J. Okolowicz (2025)
- B(E2↑) strength in ^{36}Ca and ^{38}Ca J. Okolowicz, M. Ploszajczak, arXiv:2412.16362

Symmetries in nuclei

Symmetries in nuclei

- One permanent and (usually) one post-doctoral position. Since 2012 four Marie Curie-Skłodowska fellows: K. Nomura, P. Georgoudis, N. Gavrielov & B. Maheshwari (current).
- Teaching: Course on “Symmetries of Quantum Many-Body Systems” at the University of Caen (M2).
- Training: Supervision of projects of M2 students every year from September to January since 2018.

- Scientific output: 3 books, 292 articles in refereed journals, ±7500 citations, h-index 40.
- Presentations: 84 seminars, 33 summer school lectures, 156 invited talks, 19 conference talks.
- Organiser or co-organiser of 19 conferences or workshops.

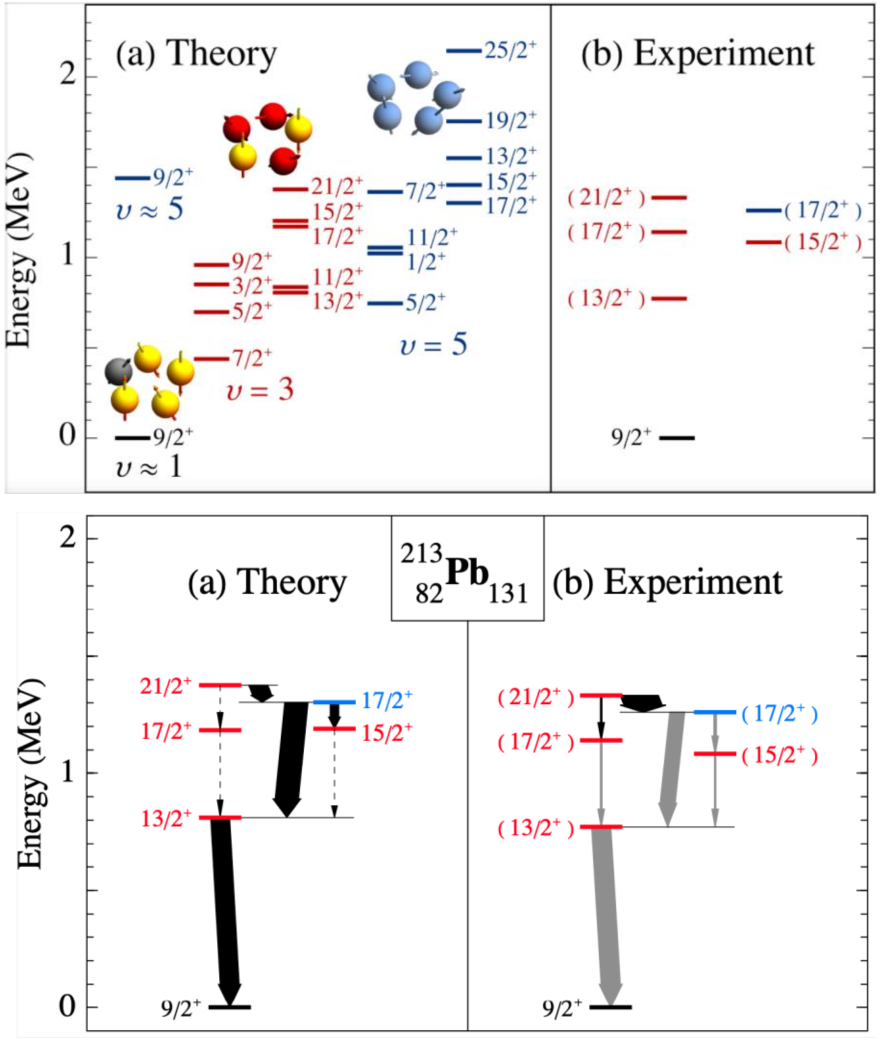
Symmetries in nuclei

- Scientific interest: Nuclear-structure calculations with the shell model and the interacting boson model.
- Emphasis on understanding problems from their symmetry structure (group theory) rather than from complicated numerical calculations.
- Specific aereas of interest: seniority quantum number, isoscalar pairing and neutron-proton pairs in N=Z nuclei, ocupole collectivity around ^{208}Pb, (state-dependent) effective E2 charges, Gamow-Teller β decay, geometry of the interacting boson model,…

- Perspectives: Structure of nuclear isomers and applications.

A. Frank, J. Jolie, P. Van Isacker, *Symmetries in Atomic Nuclei: From Isospin to Supersymmetry,* Springer Science (2008 & 2019)
P. Van Isacker, *Algebraic models of nuclei*, in *Handbook of Nuclear Physics*, Springer Nature (2022)

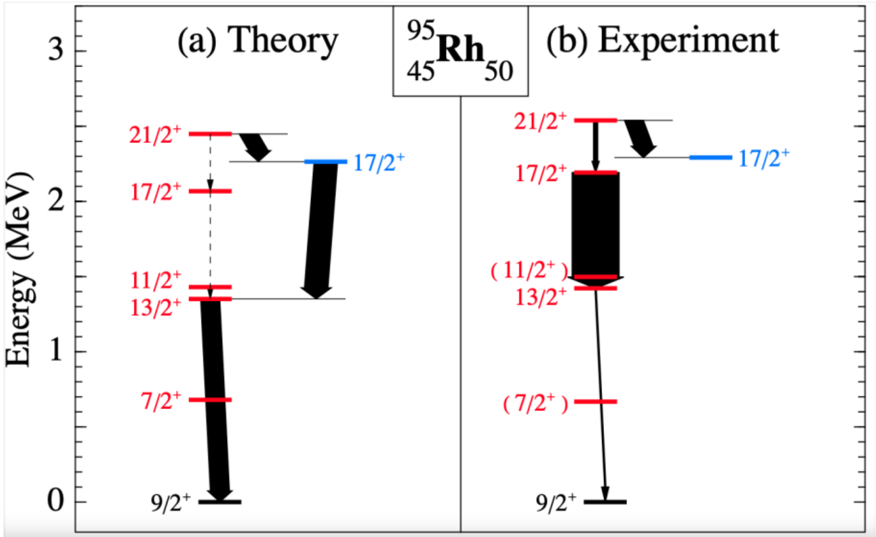
Seniority in ^{213}Pb



- In a simple approach ^{213}Pb can be described as five neutrons in the $1g_{9/2}$ orbital.
- Most states carry seniority for any interaction.
- Recent example: An experiment at GSI finds E2 transitions approximately consistent with seniority.

J.J. Valiente-Dobón *et al.*, *Manifestation of the Berry phase in atomic nuclei*, Phys. Lett. B **816** (2021) 136183

Seniority in ^{95}Rh



- In a simple approach ^{95}Rh can be described as five protons in the $0g_{9/2}$ orbital.

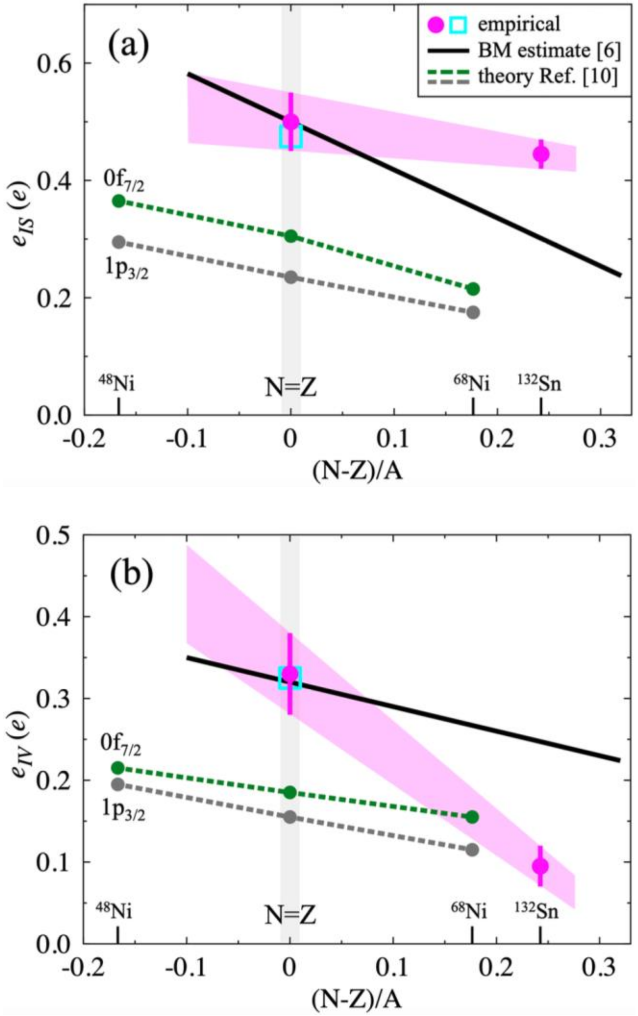
  Many states carry seniority for any interaction.

  A recent FAIR GSI experiment finds E2 transitions inconsistent with seniority.

  A more recent experiment at the Köln tandem contradicts the GSI results.

  To be continued…

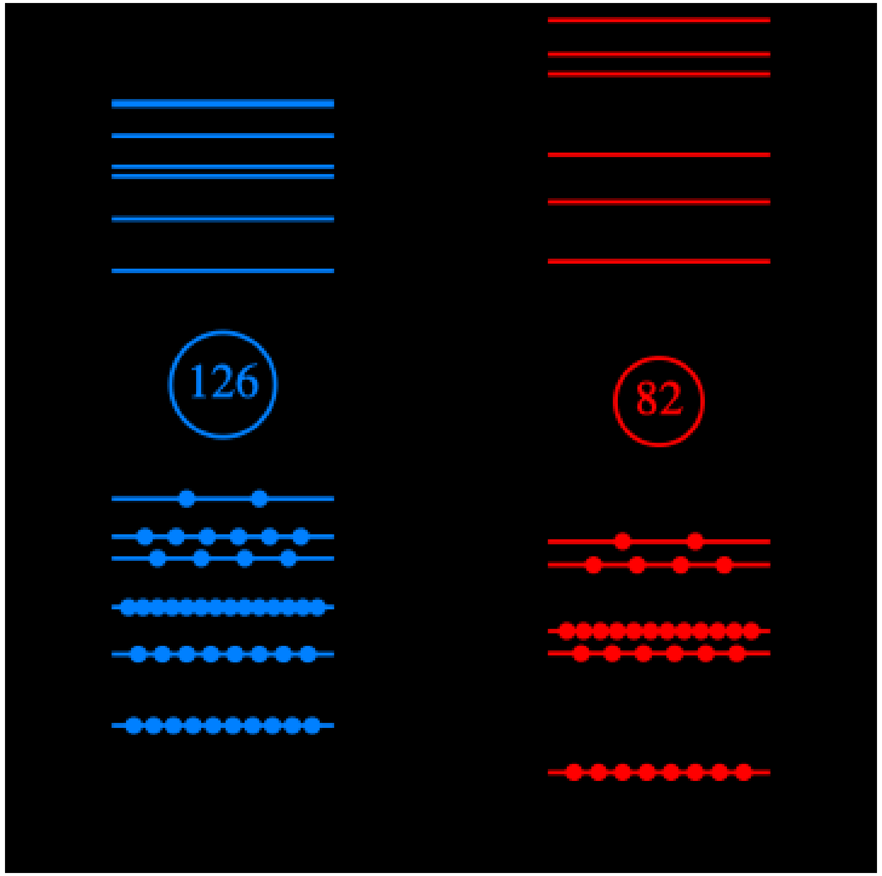
Effective E2 charges



- E2 transitions between yrast states are known in ^{98}Cd and ^{130}Cd (RIKEN experiment).
- This is a unique case to test the isospin dependence of effective E2 charges.
- The isoscalar and isovector E2 effective charges as predicted by the classical Bohr-Mottelson estimate do **not** agree with experiment).

A. Jungclaus *et al.*, *Excited-state half-lives in ^{130}Cd and the isospin dependence of effective charges*, Phys. Rev. Lett. **132** (2024)

Octupole collectivity



Goal: Microscopic study of octupole collectivity.

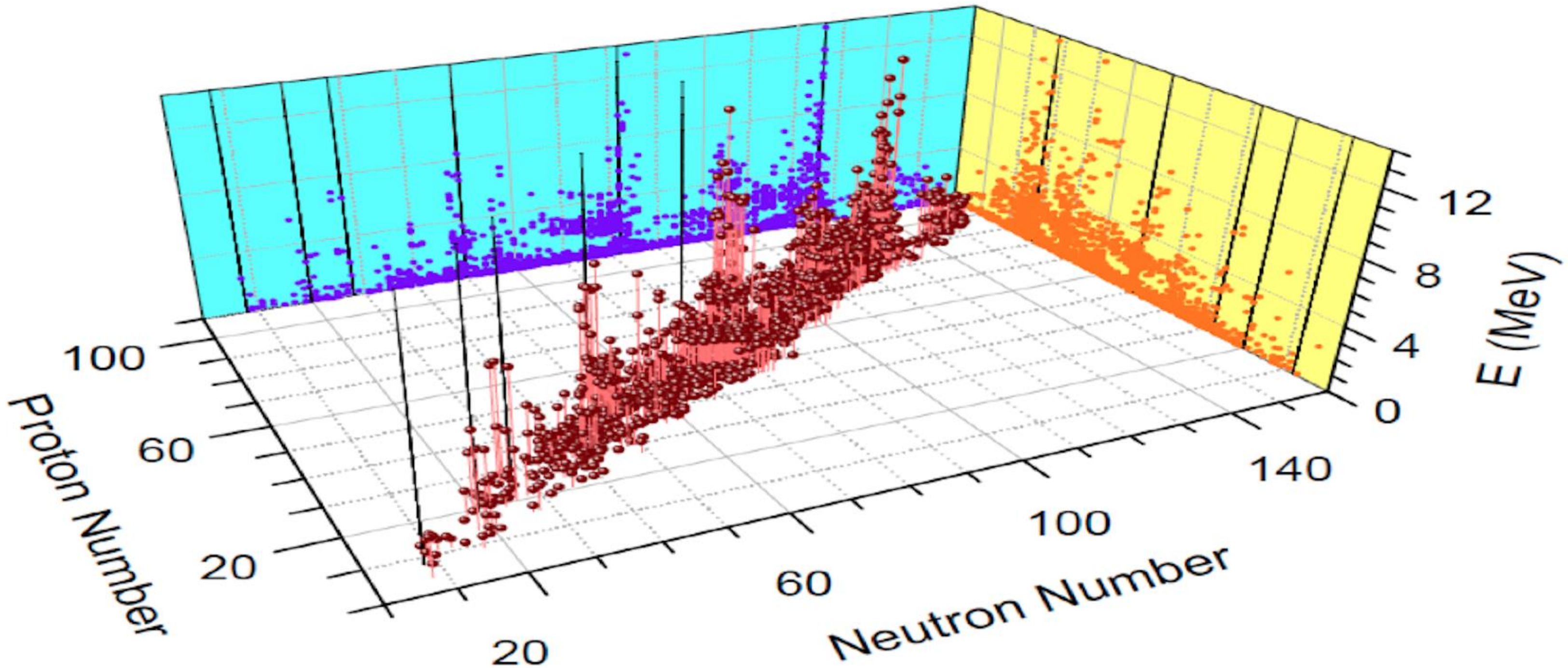
Shell model with schematic interaction (SDI) and degenerate single-particle energies is solvable.

Realistic shell model: Octupole collectivity in ^{208}Pb is mainly due to the neutron-proton interaction in the aligned-spin configuration.

P. Van Isacker, M. Rejmund, *Shell-model study of octupole collectivity in ^{208}Pb*, Phys. Rev. Research **4** (2022) L022031
M. Rejmund, P. Van Isacker, *Microscopic origins of octupole collectivity in doubly-magic ^{208}Pb*, Phys. Rev. C Lett. (2025) in press

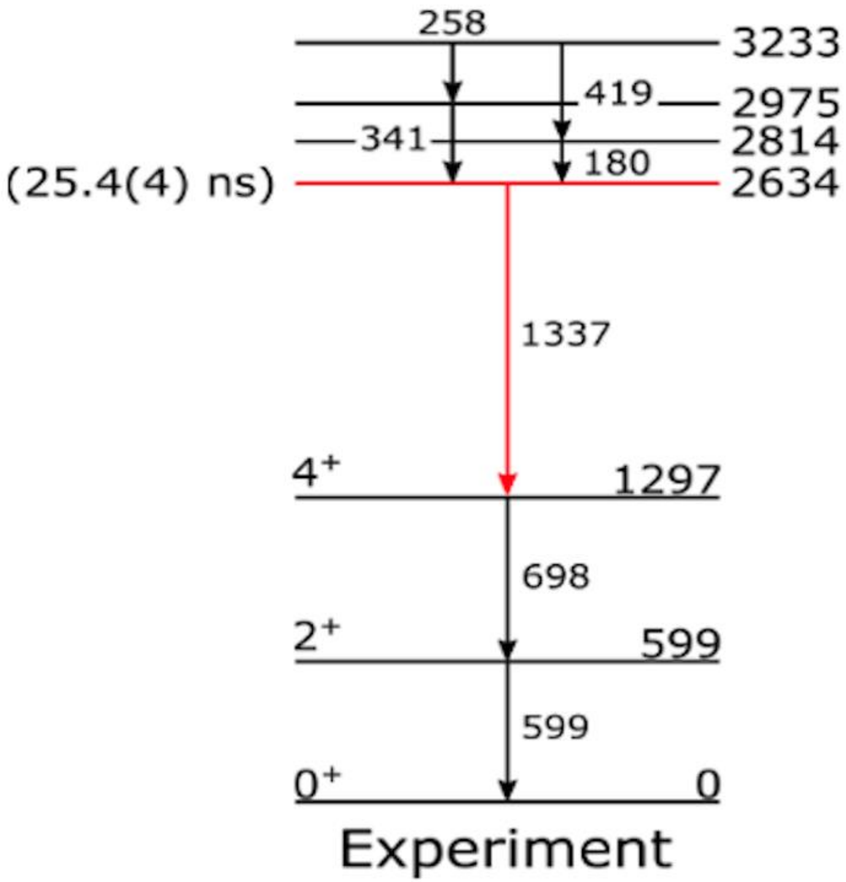
Nuclear isomers

- About 2500 metastable excited states with a half-life longer than 10 ns are known in nuclei.
- The MSCA project ISOON (Bhoomika Maheshwari) focusses on the structure of isomers, in particular in odd-odd nuclei.



A.K. Jain, B. Maheshwari, A. Goel, Nuclear Isomers - A Primer, Springer Nature (2021)
P. Van Isacker, *Seniority isomers and particle-hole conjugation*, Eur. Phys. J. Spec. Topics **233** (2023) 921

E1 transitions



E1 transitions are notoriously difficult to describe in the nuclear shell model:

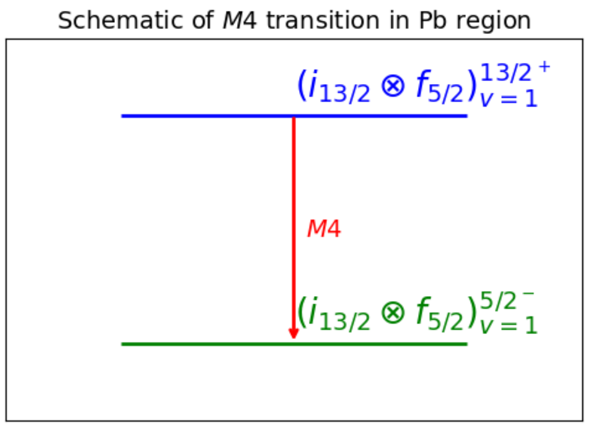
- At least two major shells;
- Spurious centre-of-mass motion;
- Strong polarisation effects.

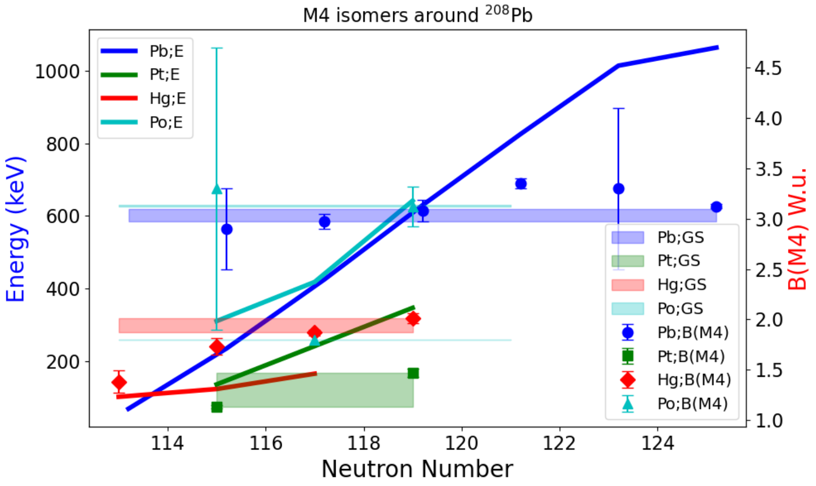
⟹ A semi-analytic approach.

Test case: $(5^-) \rightarrow 4^+$ ($T_{1/2}$=25 ns) in ^{76}Zn.

- Collaboration with B. Olaizola.

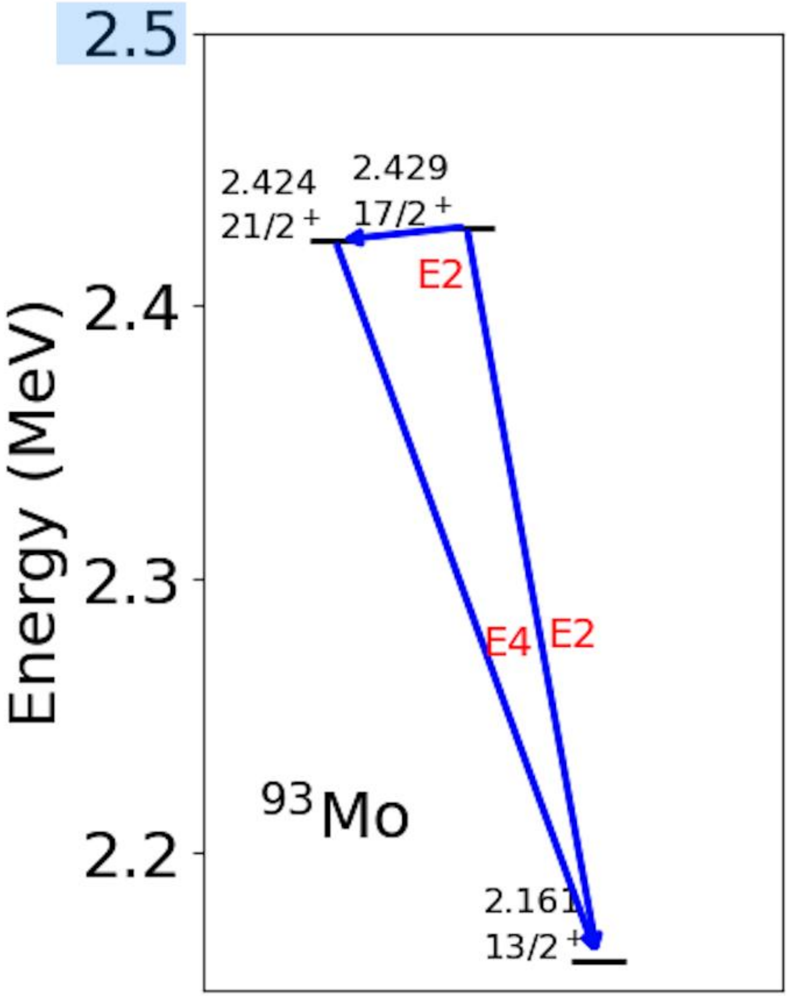
M4 transitions





- Several isomers in the Pb region are associated with an M4 transition $13/2^+ \rightarrow 5/2^-$.
- Near-constancy of B(M4) in odd-mass Pb isotopes follows from generalised seniority.
- Can this behaviour be understood in large-scale shell-model calculations?
- Do we understand the extreme quenching of the M4 matrix element?

Battery isomers



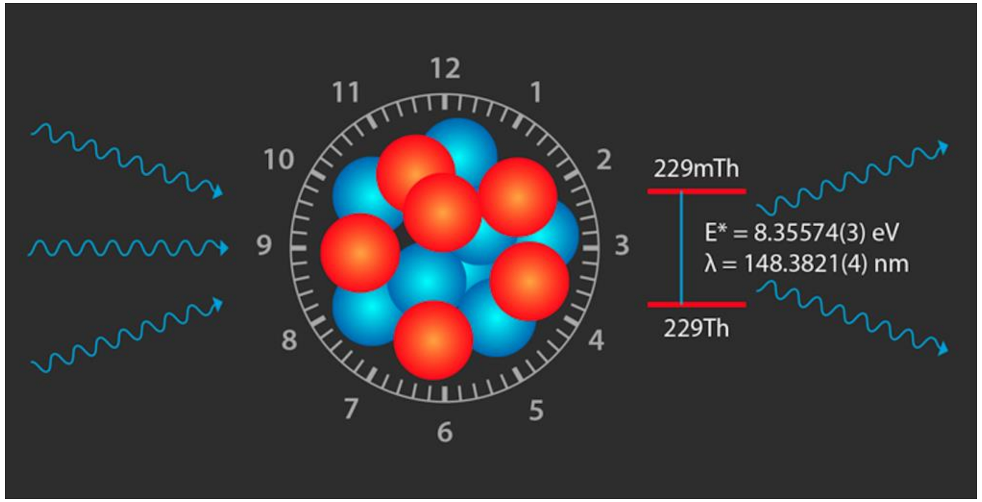
- Isomer depletion (transfer from a long-lived to a shorter-lived state) may provide a means of future energy storage.
- About ten so-called battery isomers exist of potential interest.
- An understanding of the structure of isomers and transitions is required.
- Test case: ^{93}Mo, $T_{1/2}(21/2^+)$=6.85 hours.

- Collaboration with P. Walker.

Nuclear clock: ^{229}Th

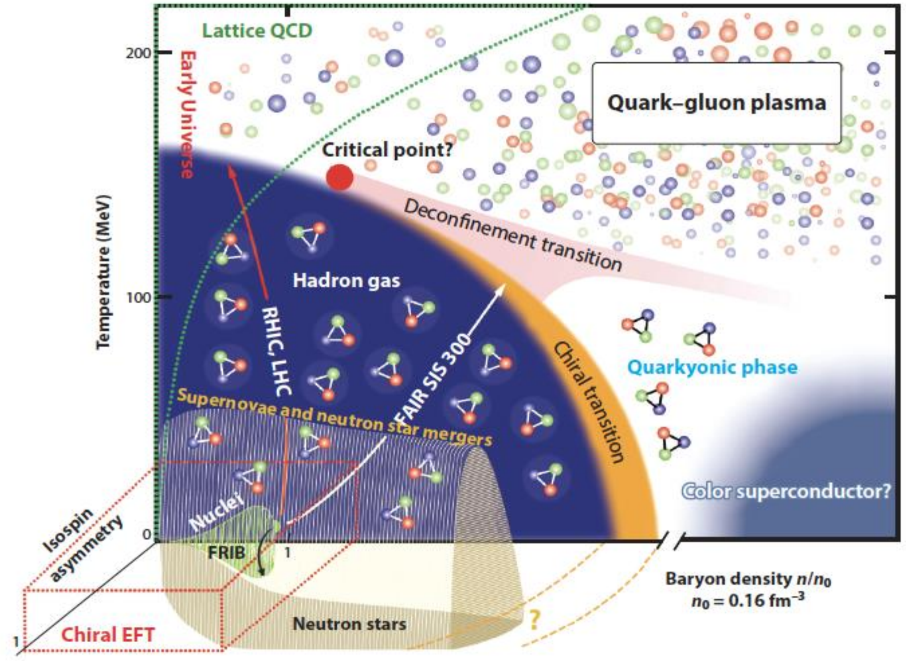
- A very low-energy γ transition may lead to the realisation of a nuclear clock.
- An understanding of the structure of this isomer is needed.

- Collaboration with N. Gavrielov.



Modelling of compact stars

Modelling of compact stars (microscopic + macroscopic description)
Supernovae, Neutron stars, White dwarfs



Drischler et al., Ann. Rev. Nucl. Part. Sci. 71, 403 (2021)

- Compact objects span very wide and extreme conditions
  (Oertel et al. 2017; Burgio & Fantina, ASSL Springer 2018)

Temperature	$0 \text{ MeV} \leq T < 150 \text{ MeV}$
Baryon number density	$10^{-11} \text{ fm}^{-3} < n_B < 10 \text{ fm}^{-3}$
Electron fraction	$0 < Y_e < 0.6$

  → need of theoretical models

- New data and astro observations from current and new-generation detectors
  → need of more realistic and consistent models of compact objects based on reliable nuclear inputs

Aim: provide consistent microphysics inputs for compact-star modelling using up-to-date nuclear models satisfying constraints from nuclear physics and astrophysics
→ better evaluation of theoretical uncertainties and impact on astrophysical observables

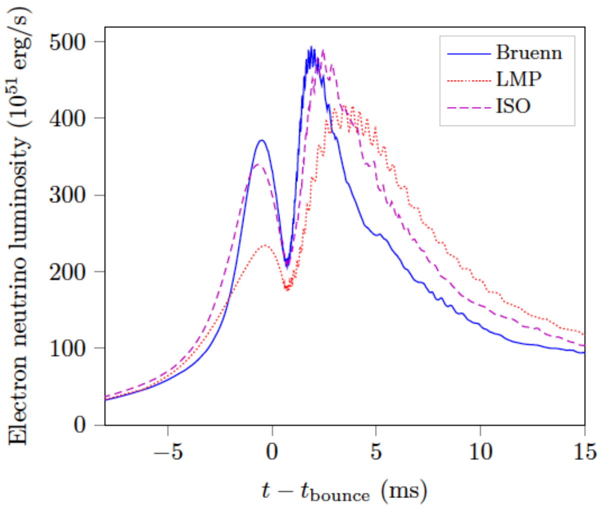
→ Continuity and extension of current research activities (within national and international collaborations, e.g. IN2P3 MP MAC, IRP France-Belgium ACNu, LUTH-Caen group in Virgo collab.)

Modelling of compact stars (microscopic + macroscopic description)

❖ **Supernovae (SN)**

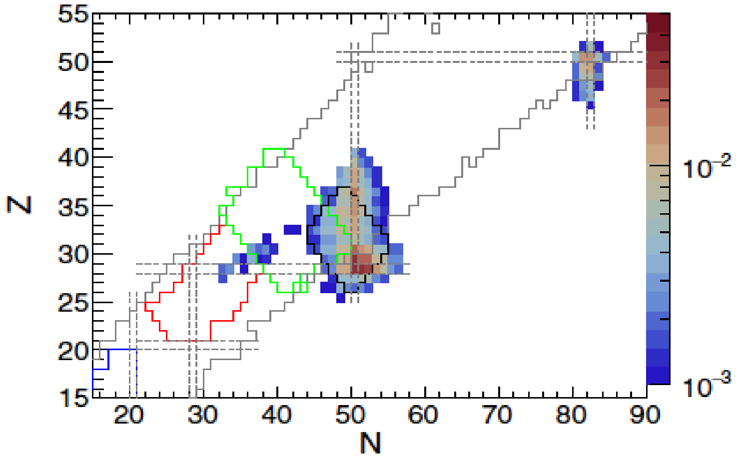
- Equations of state (EoSs) at finite temperature and out-of-(beta-)equilibrium
- Electro-weak (electron-capture, EC) rates
- Impact of nuclear inputs (EoS, EC, nuclear masses) in core-collapse SN simulations

Grams et al. [**Giraud**, Fantina], PRC 97, 035807 (2018); Pascal et al. [**Giraud**, Fantina], PRC 101, 015803 (2020); **Giraud** et al. [Bastin, Fantina, De Oliveira], PLB 833, 137309 (2022) – experiment I220



Pascal et al., PRC 2020

Neutrino luminosity at bounce for different EC rates



Pascal et al., PRC 2020

Most relevant nuclei for EC during collapse

- ✓ Importance of EC rates in core-collapse dynamics
- ✓ Importance of consistent implementation of nuclear inputs in simulations
- ✓ Most relevant nuclei for EC around N=50 shell closure

  but: no exp/theo info on most of these nuclei

- ➢ Provide better estimated of EC rates (with E. Litvinova, WMU and visiting scientist at GANIL)

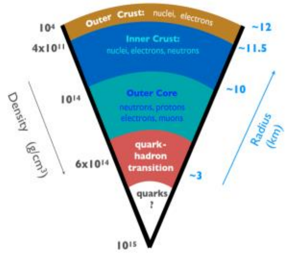
  → Benchmark calculations with up-to-date microscopic many-body approach validated on experimental data
- ➢ Calibrate flexible parametrization for EC rates for SN simulations

Modelling of compact stars (microscopic + macroscopic description)

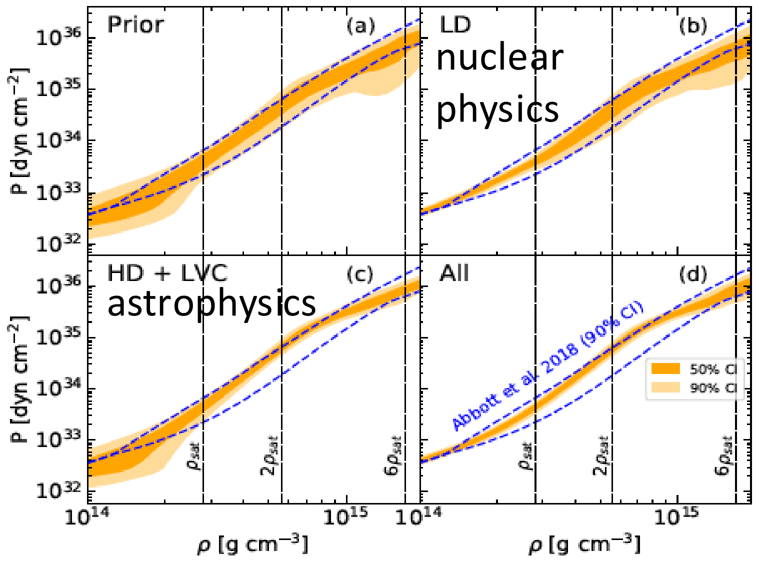
❖ **Neutron stars in** full equilibrium

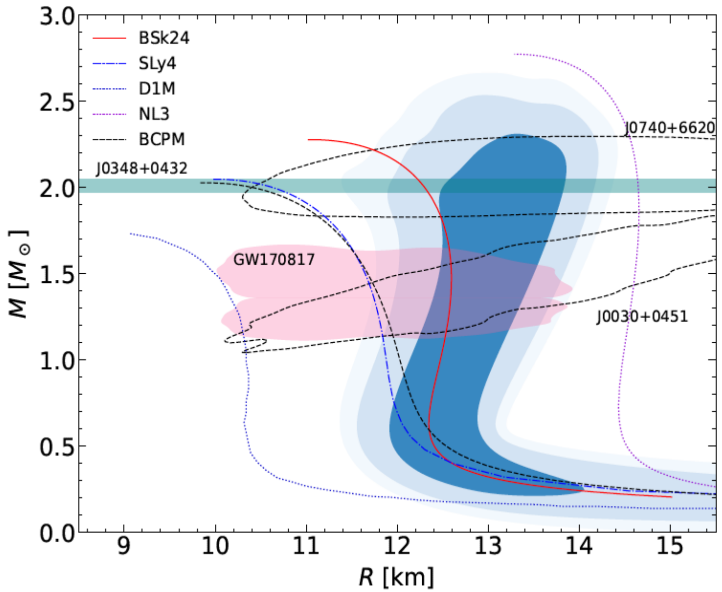
- Unified EoSs and composition (including non-spherical clusters: “pasta phases”)
- Bayesian analysis to assess theoretical uncertainties

Pearson et al. [Fantina], MNRAS 481, 2994 (2018); Gulminelli&Fantina, Nucl. Phys. News 31, 9 (2021);
Dinh Thi et al. [Fantina], A&A 654, A114 (2021); EPJA 57, 296 (2021); **Dinh Thi** PhD thesis (2023)



Credit: 3G Science White Paper





Dinh Thi et al., Universe 2021; Dinh Thi et al., A&A 2021

Gulminelli&Fantina, NPN 2021; Fantina&Gulminelli, J.Phys. 2023

Posterior of the EoS with different constraints and corresponding predictions of M-R relation

✓ Determine importance of EoS parameters

✓ Combined constraints
→ comparison with observations

✓ Quantify uncertainties and impact on astro observables

➢ Calculations of (unified) EoSs, transport properties

➢ Bayesian analyses to assess theoretical uncertainties and impact on astrophysical observables
→ inclusion of nuclear observables (e.g. possible future use of emulators with up-to-date many-body methods)
→ nuclear-physics-informed posterior distributions of EoS parameters to be implemented in astro applications

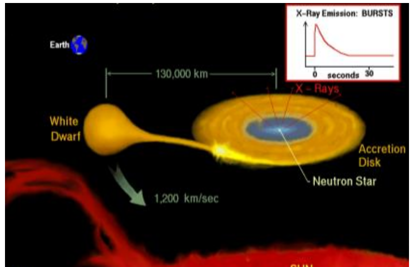
Modelling of compact stars (microscopic + macroscopic description)

❖ **Neutron stars (accreting)** – out-of-equilibrium

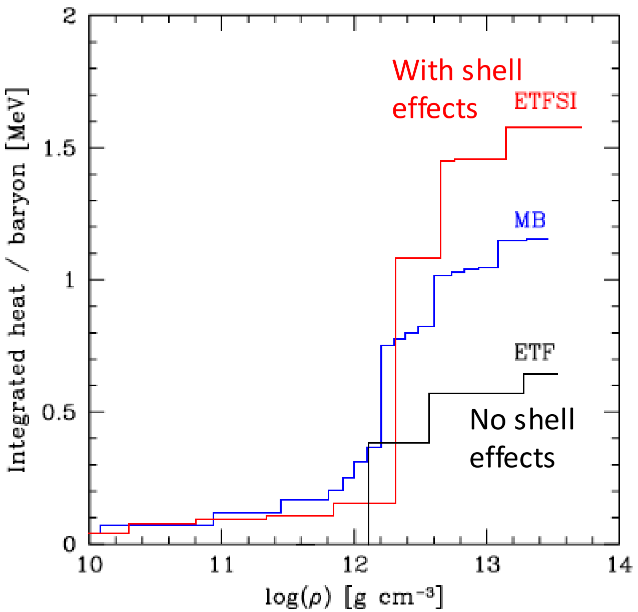
- EoS
- Composition
- Heat sources due to EC and pycnonuclear reactions

} needed for modelling thermal evolution & to compare with observations

Fantina et al., A&A 620, A105 (2018); Fantina et al., A&A 665, A74 (2022) ; Chamel, Fantina, et al., PRC 102, 015804 (2020)

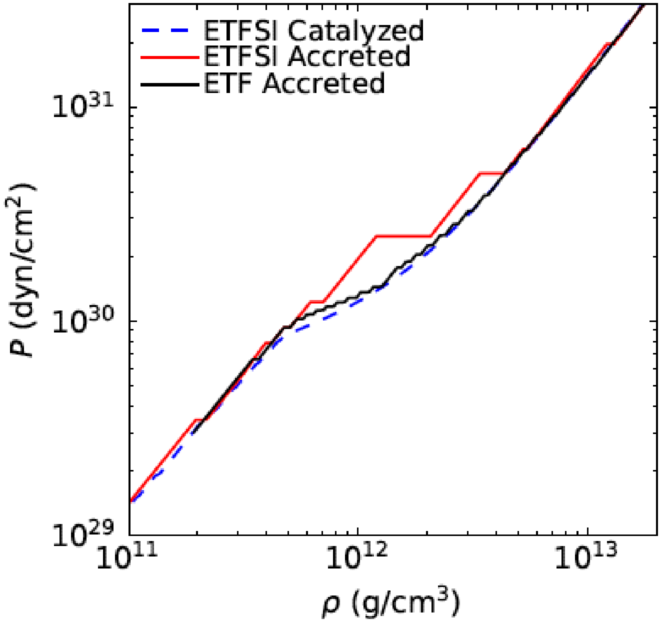


NASA/HEASARC; http://www.astroscu.unam.mx



Fantina et al., A&A 2018

Heat released → impact of shell effects



Fantina et al., A&A 2022

EoS of accreting vs non-accreting NS

✓ Importance of structure (shell) effects

✓ EoS of crust different wrt non-accreting one

N.B.: Heat released also in magnetars' crusts

Chamel, Fantina, et al., Universe 7, 193 (2021);
Chamel&Fantina, Universe 8, 328 (2022)

Data available for both non-accreting and accreting NSs, and for magnetars for astrophysical simulations

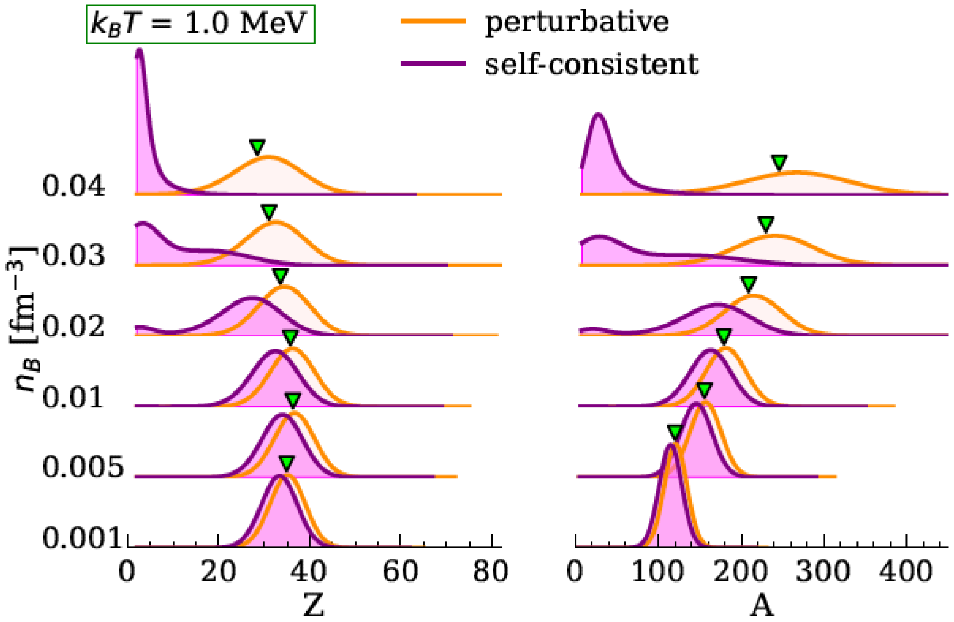
N.B.: not many models available for accreting NSs

Modelling of compact stars (microscopic + macroscopic description)

- **(Proto-)neutron stars at finite temperature**
  - Finite-temperature EoS, composition accounting for full nuclear distribution
  - Crystallization and crust formation

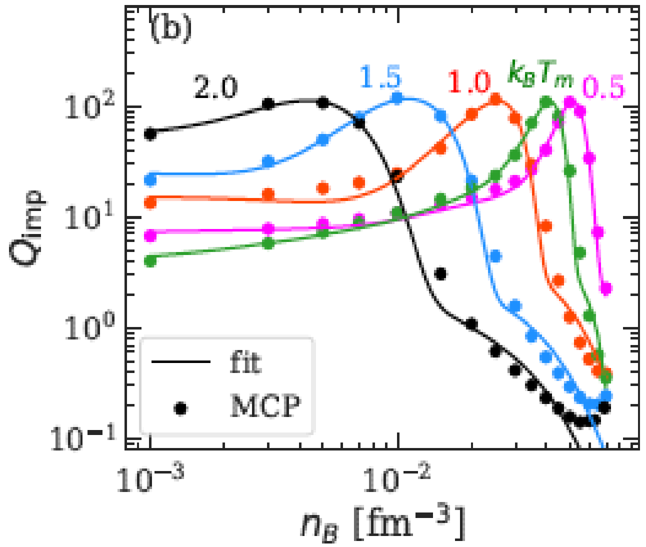
  → consistent calculation of impurity parameter (usually taken as free parameter adjusted to cooling observation)

Fantina et al., A&A 633, A149 (2020); Carreau et al. [Fantina], A&A 635, A84 (2020); Carreau et al. [Fantina], A&A 640, A77 (2020);
Dinh Thi et al. [Fantina], A&A 672, A160; A&A 677, A174 (2023); EPJA 59, 292 (2023); **Dinh Thi**, PhD thesis (2023)



Dinh Thi et al., A&A 2023

Self-consistent vs perturbative and one-component approach



Consistent calculations of impurity parameter + analytical fit

✓ Importance of (self-)consistent calculations of nuclear distribution

✓ Consistent calculations of impurity parameter

Data available for astrophysical simulations

➢ Calculations of EoS and composition with nuclear distributions, and also of transport and elastic properties (needed for astro simulations)
  → impact on NS evolution, modes, …

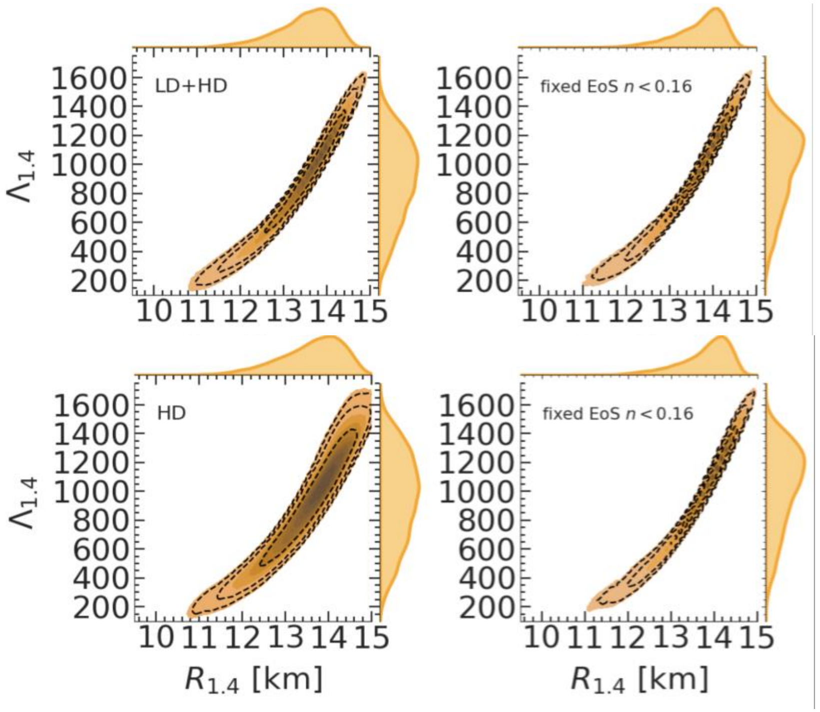
➢ Better description of clusters in hot dense medium (PhD thesis **T. Diverres**, ongoing)

Modelling of compact stars (microscopic + macroscopic description)

❖ **Neutron stars (contribution to Virgo within the LUTH-Caen group)**

- Analysis tools: EoS tables, unified (nuclear-physics-informed) EoS tool for parameter estimation

Davis et al. [Fantina], A&A 687, A44 (2024); Davis et al. [Fantina], EPJA submitted



Davis et al., A&A 2024; Fantina & Gulminelli, PoS (in press)

Joint distribution of tidal deformability and radius with consistent (left) or non-unified (right) EoS

✓ Use of non-unified EoS does not change much averages (few %)
→ OK for current detectors but next-generation ones?

✓ Underestimation of uncertainties in non-consistent approach

CUTER tool to construct unified and consistent EoS:
v1 delivered to LVK collaboration in May 2023 and on Zenodo
v2 delivered to LVK in Aug. 2024
+ developments in progress

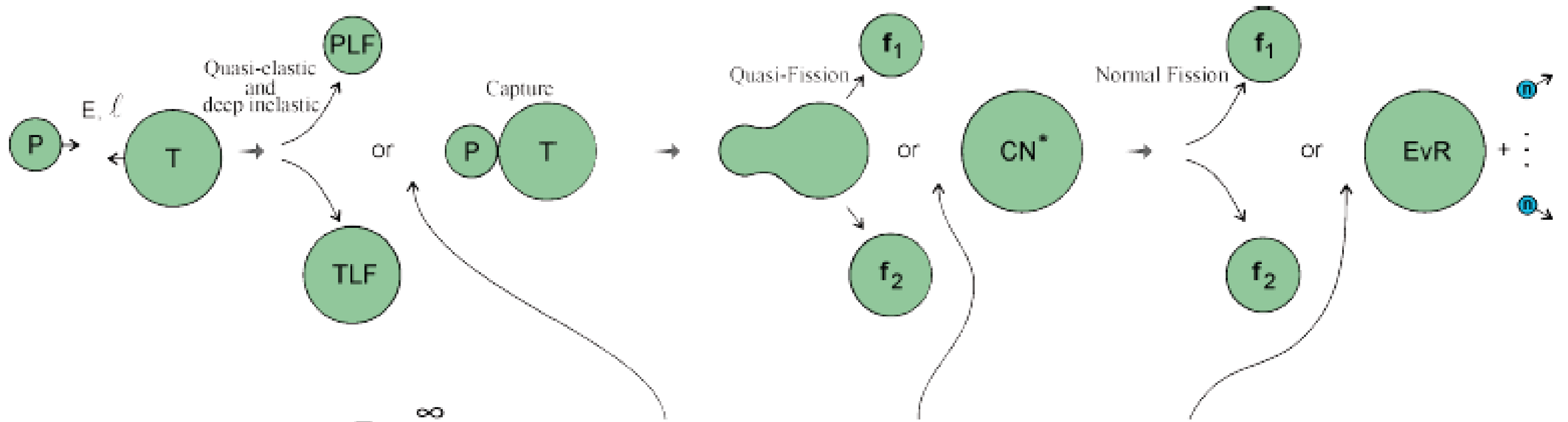
➢ Provide expertise in nuclear and NS physics for inference of dense-matter properties within LUTH-Caen group in the Virgo collaboration

➢ Development of EoSs and tools for parameter estimation

Reaction mechanisms to synthesize super-heavy nuclei

Reaction to form SHE

Synthesis of SHE in fusion reactions (conventional view)



$$\sigma_{ER}^{xn}(E) = \frac{\pi}{k^2}\sum_{\ell=0}^{\infty}(2\ell+1)\cdot P_{cont}(\ell,E)\cdot P_{CN}(\ell,E^*)\cdot P_{xn}(\ell,E^*)$$

KEWPIE2 code

Computer Physics Communications 200 (2016) 381–399

Contents lists available at ScienceDirect

Computer Physics Communications

journal homepage: www.elsevier.com/locate/cpc

ELSEVIER

KEWPIE2: A cascade code for the study of dynamical decay of excited nuclei[☆]

CrossMark

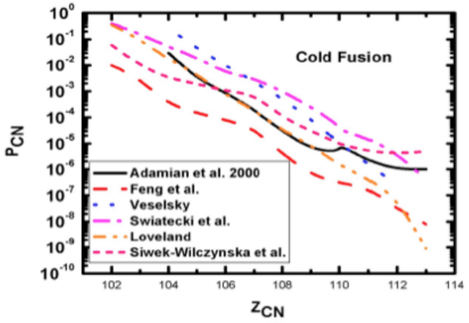
Hongliang Lü[a,b], Anthony Marchix[a,b,d,*], Yasuhisa Abe[c], David Boilley[a,b,*]

Comparison of various models

σ_{cap} x

Well known

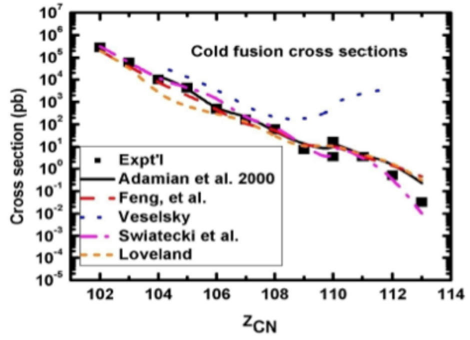
Naik, Loveland et al, Phys. Rev. C **76**, 054604



Unknown
2 orders of magnitude between models

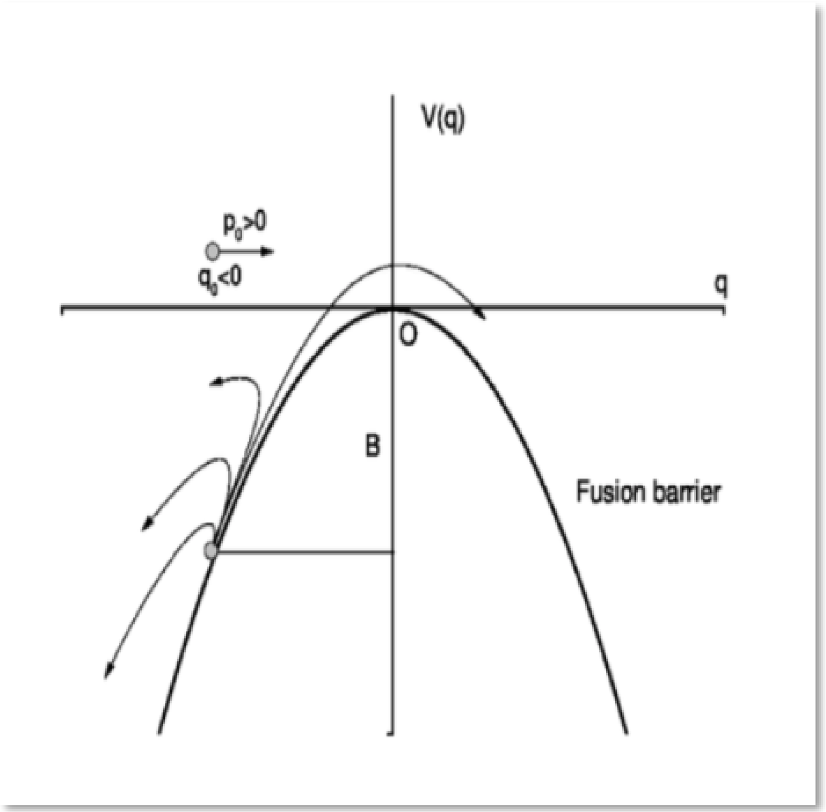
x P_{sur}=

Well known



Uncertainty analysis: PhD thesis of H. Lü and B. Cauchois

Elimination of fast variables

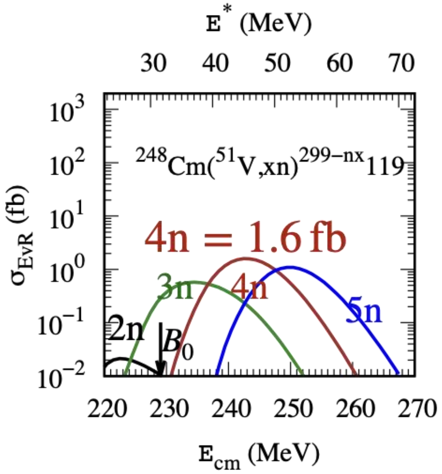


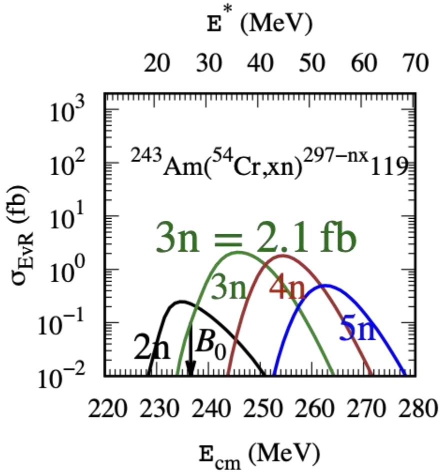
- N-dimension problem
- Fast variables are eliminated after a sho
- Slow variables start at τ with a slipped initial condition due to the coupling to the fast variables

-> Revisit the formation part of the fusion-by-diffusion model in Donglo's PhD thesis

Race to Elements with Atomic Number 119 and 120

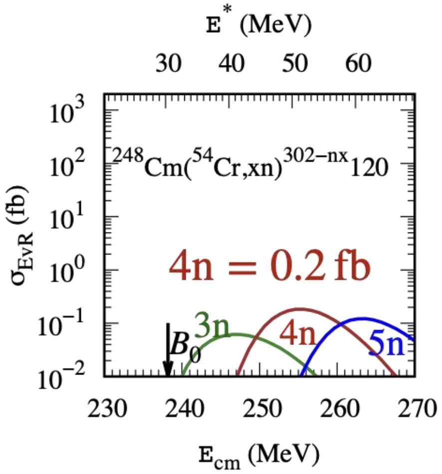
Japan [1]

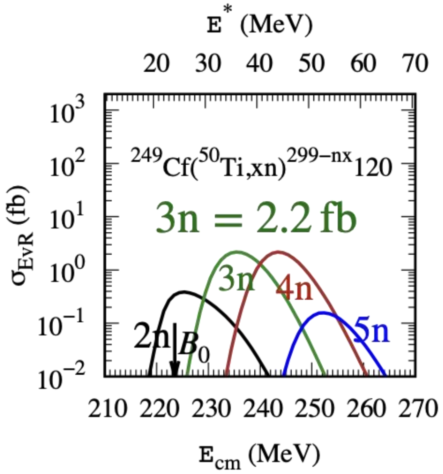




[2] China

Russia [3]





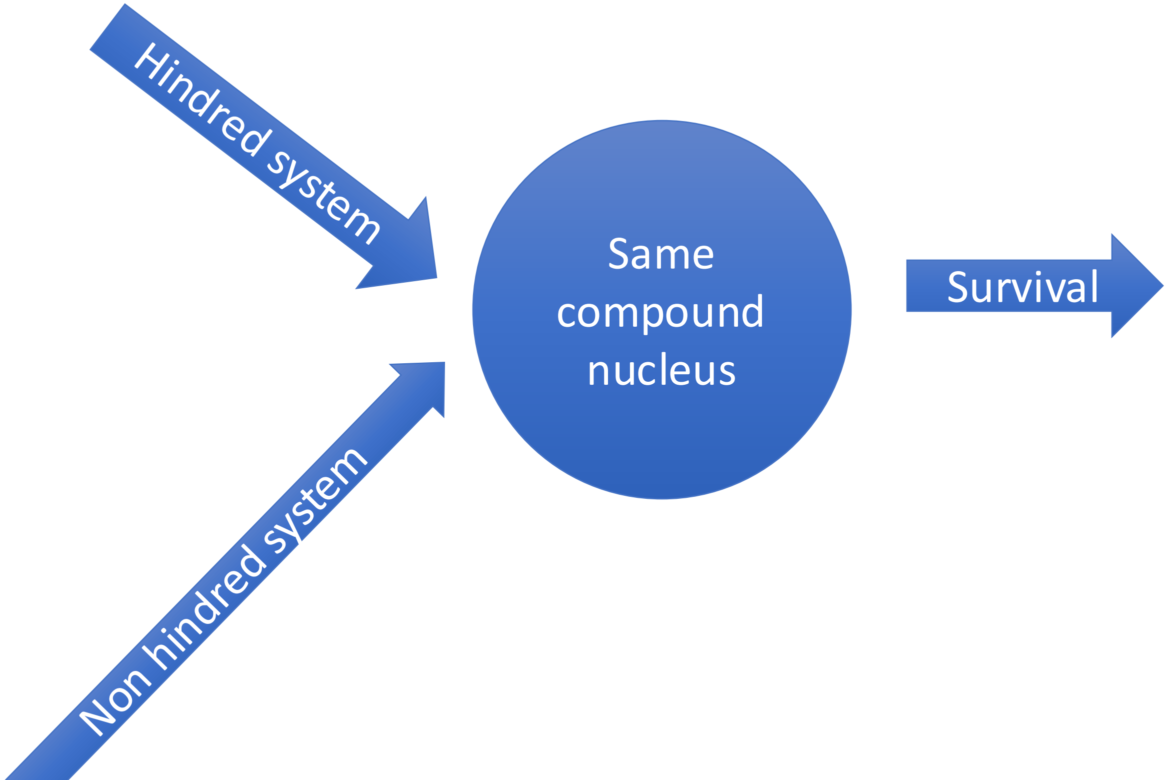
[4] USA

✤Production Cross sections in the order femto barn poses a experimental challenge

[1]M. Tanaka et al., J. Phys. Soc. Jpn. 91(8), 084201 (2022)
[2]L. Sun et al., Phys. Rev. C 110(1), 014319 (2024)
[3]S. Chopra et al., Physical Review C 110 (2024) 014615.
[4]J. M. Gates et al., arXiv 2407.16079 (2024)

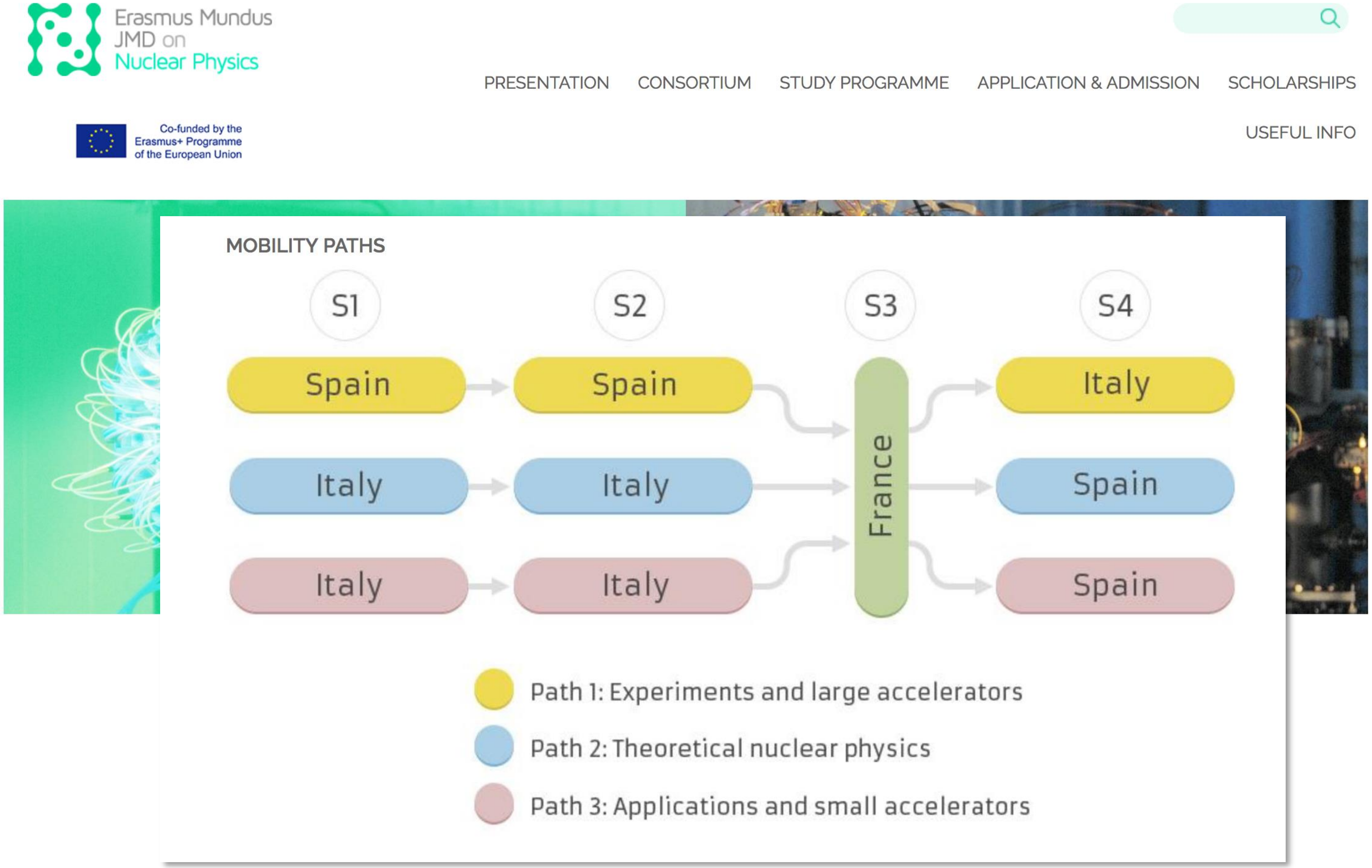
Future developments

- Formation dynamics on a mic-mac potential map
- Find observables that can constrain better the models



Collaborations

- 5 PhD students
- Past collaborations with Osaka and Huzhou universities
- Current collaboration with the NCBJ and Warsaw university
- Collaboration foreseen with Lund university



http://www.emm-nucphys.eu/

Needs of a renewed theory group

- Permanent positions

- Calculation capacities