UK Nuclear Theory

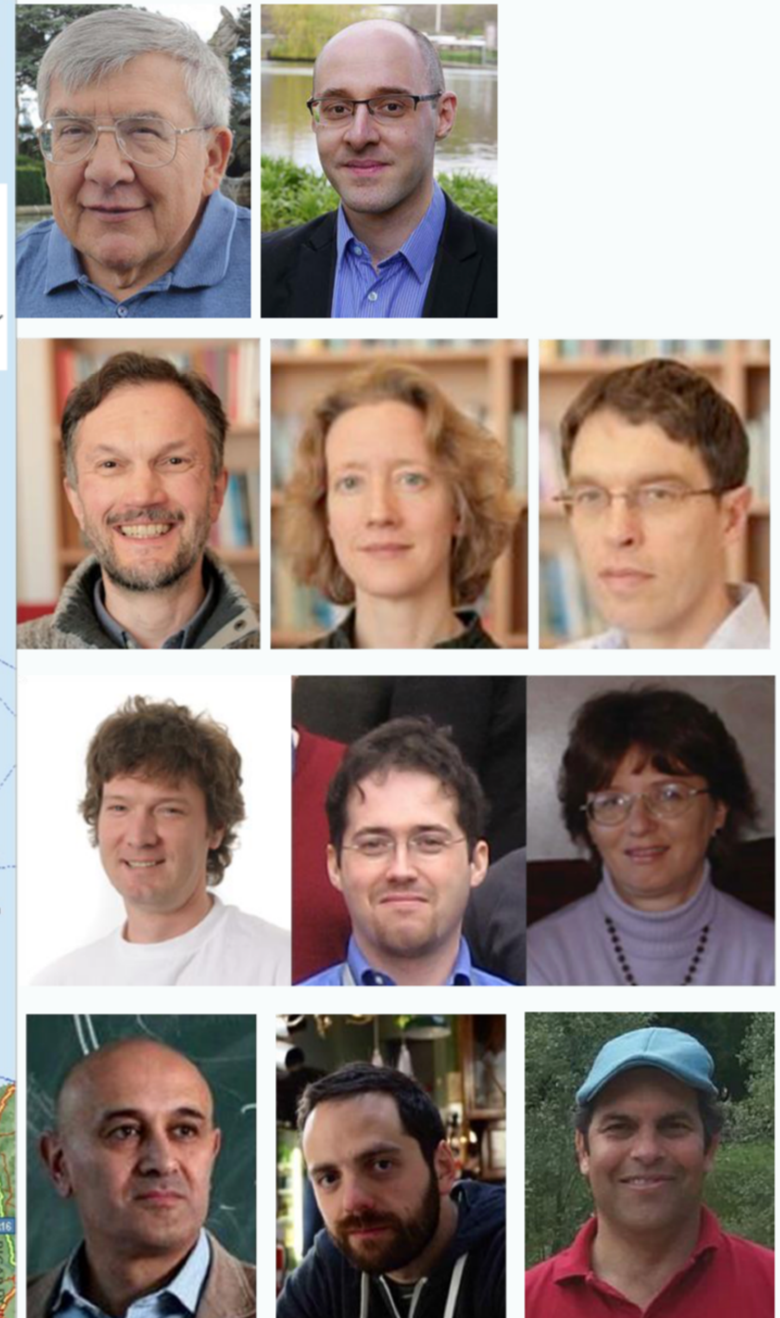
Warwick Jan 2019

Judith McGovern

University of Manchester

UK Theory community

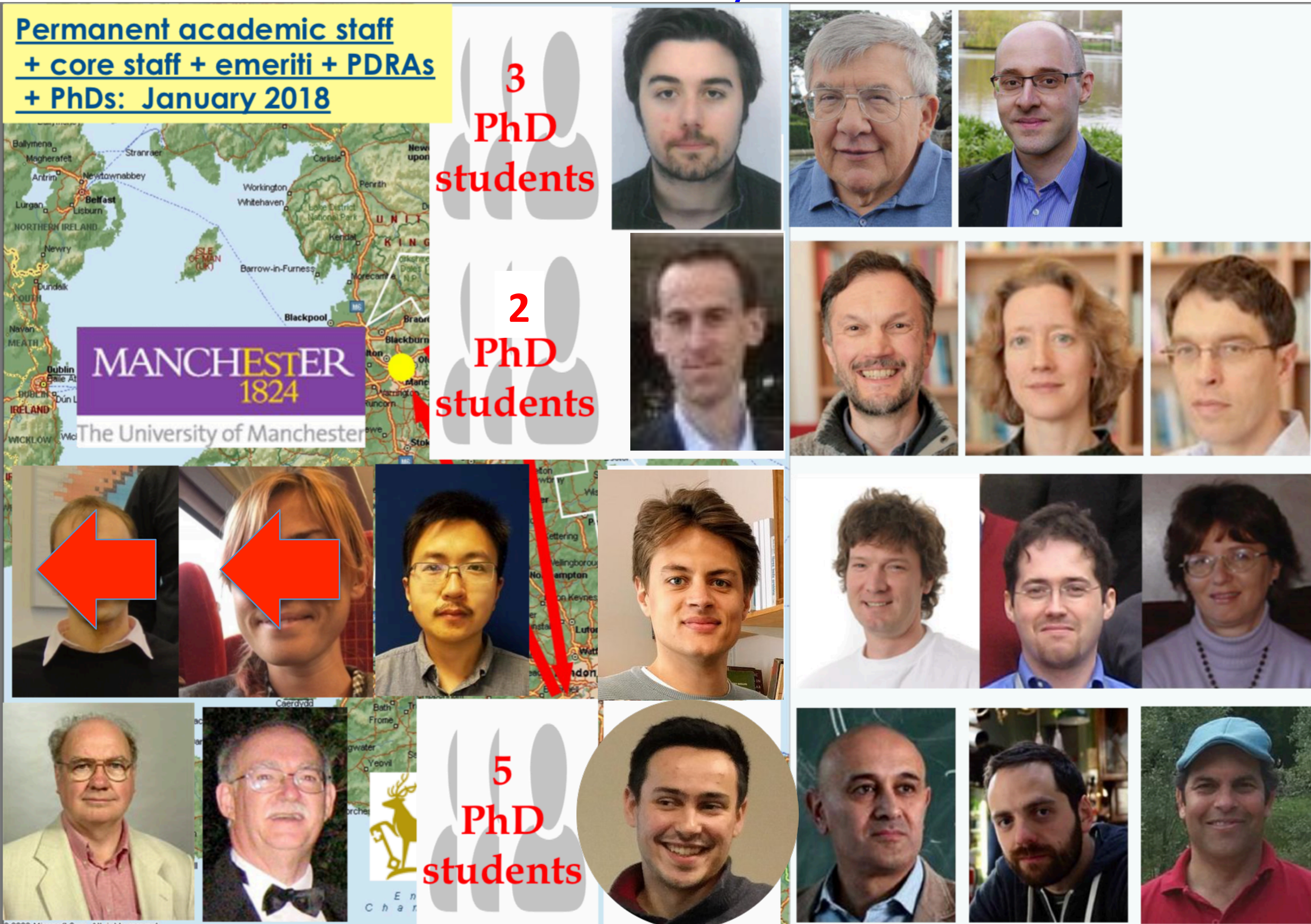
Permanent academic staff + core staff: January 2019



January 2018

January 2019

January 2019



Nuclear Theory Vision @ UK

STFC funding for the **benefit of the entire UK** nuclear theory

→3 international **TALENT courses**

Summer 2016: Nuclear DFT @ York, 3 weeks.
Summer 2018: **?????**
Summer 2019: **?????**

→Regular (twice a year) **1-day theory meetings**

November 2015 @ Manchester
May 2016 @ York
November 2016 @ Surrey
May 2017 @ Manchester
November 2017 @ York
Experimentalists welcome!

→Visitor programme (High-profile and/or task-oriented):

April 2016 : Jeremy Holt
October 2016 : Tetsuo Hatsuda
January 2017 : Isaac Vidaña
February 2017 : Olga Rubtsova
May 2017 : D. Davesne
May 2017 : V. Somà
October 2017 : M. Gomez Ramos
November 2017 : L. Próchniak
Suggestions welcome!

http://personal.ph.surrey.ac.uk/%7Ecb0023/uktheory/Nuclear_Theory_Vision_%40_UK/Nuclear_Theory_Vision_%40_UK.html

Nuclear Theory Vision @ UK

STFC funding for the **benefit of the entire UK** nuclear theory

→3 international **TALENT courses**

Summer 2016: Nuclear DFT @ York, 3 weeks.

Summer 2019: Learning from Data – Bayesian methods and machine learning @ York, June 10-18 Applications open!

→Regular (twice a year) **1-day theory meetings**

May 2018 @ Surrey
November 2018 @ Manchester
May 2019 @York

May 2017 @ Manchester
November 2017 @ York
Experimentalists welcome!

→Visitor programme (High-profile and/or task-oriented):

M. Gomez Ramos – Nov 2018
V. Somà - Feb. 5-9, 2018
T. Duguet - Feb. 5-9, 2018
A. Carbone - Jan.-Feb. 2018

May 2017 : D. Davesne
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October 2017 : M. Gomez Ramos
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Roadmap 2018

Roadmap 2018

Recommendations:

The UK should support flagship projects in Nuclear and Hadronic physics including upgrades that capitalise on previous investments, maximise high-quality science output and UK leadership in international projects**. Funding solutions to support capability building within the Nuclear Theory community to support the scientific programme both at a multi institutional and multi-disciplinary level should be investigated.**

Roadmap 2018

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The UK should support flagship projects in Nuclear and Hadronic physics including upgrades that capitalise on previous investments, maximise high-quality science output and UK leadership in international projects**. Funding solutions to support capability building within the Nuclear Theory community to support the scientific programme both at a multi institutional and multi-disciplinary level should be investigated.**

2: Facilities

The theory community gives the ECT* its strongest possible support, noting also that it is widely used by nuclear experimentalists and by theorists and experimentalists from other parts of the STFC community, and that it enables fruitful dialogue between all of these constituencies. A series of workshops is organised each year covering a wide range of nuclear physics topics with an emphasis on theory. The UK has taken leadership on organising a number of workshops. **STFC should continue to support UK membership of ECT*.**

Roadmap 2018

3.3.2 Future opportunities and projects

With the present intellectual environment, the UK theory community will seek to further leadership roles over the next few years. Opportunities from the advent of new facilities will demand advances in reaction theory on several fronts. In an international setting in which reaction theorists are in demand, the UK could easily capitalise on its expertise and expand the efforts in this sub field. The DFT and ab- initio groups have a unique opportunity to pursue a new generation of EDFs that are derived from first principles. On the one hand, first principle calculations are necessary, for example to address data on radii and masses coming from ISOLDE (CERN) and TITAN (TRIUMF) and data on nuclear correlations from R3B (GSI) and RIKEN. On the other hand, new and more accurate functionals will open path to addressing several question in heavy nuclei and specific reactions governing nucleo-synthesis. Applying ab-initio theory to test our understanding of the nuclear force (with links to the EFTs and calculation from the international Lattice QCD community) will also be beneficial to improve predictions of neutron star matter and astrophysical objects.

Neutrino-nucleus interactions project: The UK theory groups have expertise both in nuclear structure and in reactions, including using modern ab-initio methods and effective field theory. This technology can be harnessed to calculate experimentally-crucial cross-sections with greater precision and sophistication than most currently-used codes. Additional expertise in nuclear structure and chiral physics would also contribute, and synergy with the UK particle experimental program is envisaged. An investment of roughly £0.5M funding for workforce and £0.4M for computer power would be required.

Theoretical studies of spontaneous and induced fission project: A proposal to develop a leadership hub for theoretical studies of spontaneous and induced fission. This will build upon expertise in self- consistent methods, building synergic connections with experimental studies. Newton fellowship funding to support PDRAs is being sought along with an ERC-AdG proposal for 0.5MEuro/year funding for manpower and 1MEuro funding for computer power.

Roadmap 2018

	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Hadronic Physics	ALICE upgrade (LHC)							
	JLAB upgrade							
				Jlab 2				
				EIC R+D				
							....	2030
							Electron Ion Collider	
	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Nuclear Structure & Astrophysics	ISOL/SRS							
	NuSTAR at FAIR							
	AGATA exploitation		AGATA upgrade					
						STA		
			ACPA@ELI					
			DRACULA FRIB					
						Instrumentation@JYFL		
							....	2030
							Future ISOL/EURISOL	
							NuSTAR UG	
	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Nuclear Theory			Neutrino-nucleus					
			Fission					
		ongoing		future		exploitation		horizon
				PRD		exploitation at other facilities inc GSI		

Figure 9: Project timescales

Highlights 2018

York

York

Jacek Dobaczewski

Pierre Becker

Alessandro Pastore

Antonio Marquez Romero

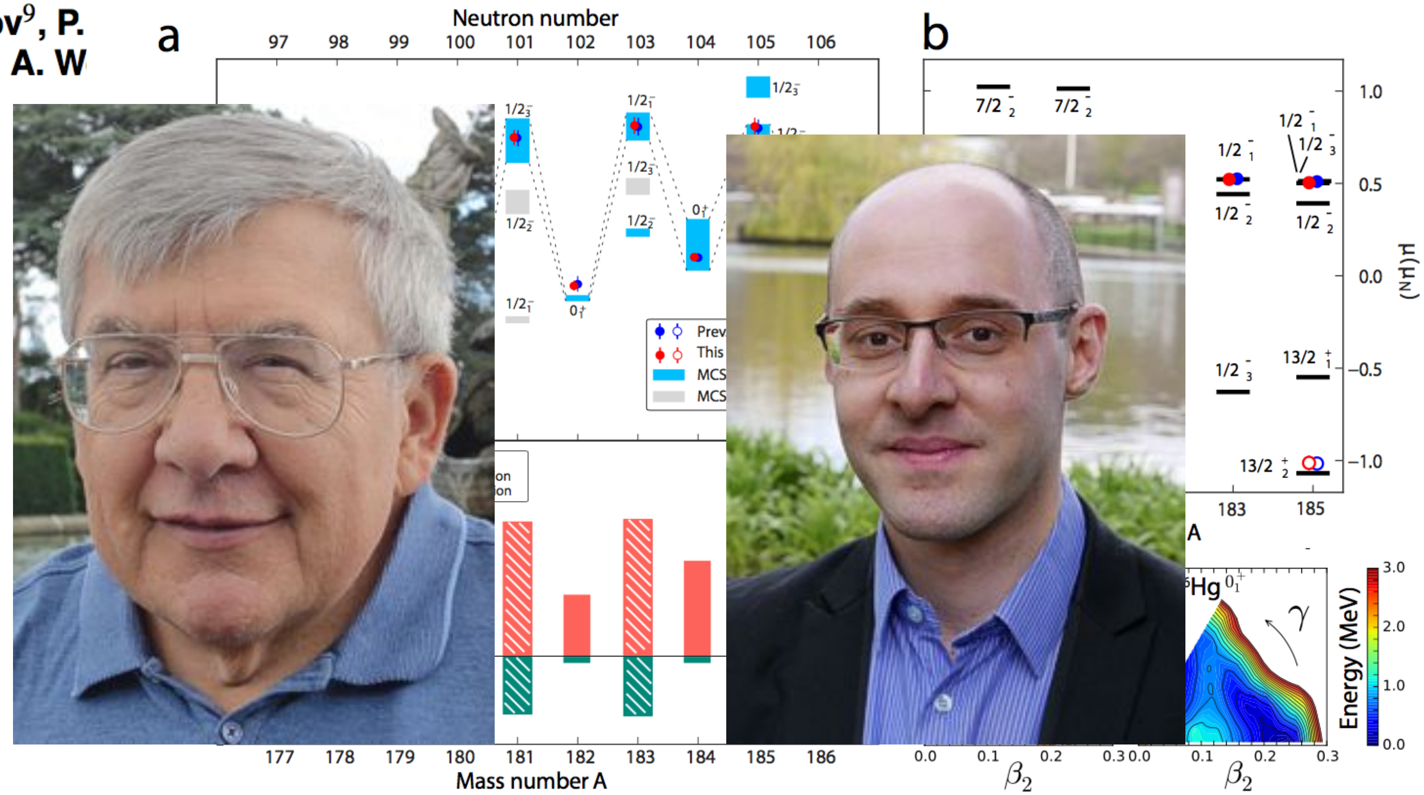
Matthew Shelley

David Muir

Characterization of the shape-staggering effect in mercury nuclei

NATuRE PHYSiCS | VOL 14 | DECEMBER 2018 | 1163–116

B. A. Marsh[1,*], T. Day Goodacre[1,2,+], S. Sels[3,+], Y. Tsunoda[4], B. Andel[5], A. N. Andreyev[6,7], N. A. Althubiti[2], D. Atanasov[8], A. E. Barzakh[9], J. Billowes[2], K. Blaum[8], T. E. Cocolios[2], J. G. Cubiss[6], J. Dobaczewski[6], G. J. Farooq-Smith[2], D. V. Fedorov[9], V. N. Fedosseev[1], K. T. Flanagan[2], L. P. Gaffney[3,10], L. Ghys[3], M. Huyse[3], S. Kreim[8], D. Lunney[11], K. M. Lynch[1], V. Manea[8], Y. Martinez Palenzuela[3], P. L. Molkanov[9], T. Otsuka[3,4,12,13,14], A. Pastore[6], M. Rosenbusch[13,15], R. E. Rossel[1], S. Rothe[1,2], L. Schweikhard[15],
M. D. Seliverstov[9], P.
E. Verstraelen[3], A. W
K. Zuber[16]



“By combining our experimental measurements with Monte-Carlo Shell Model calculations, we conclude that this phenomenon results from the interplay between monopole and quadrupole interactions driving a quantum phase transition, for which we identify the participating orbital”

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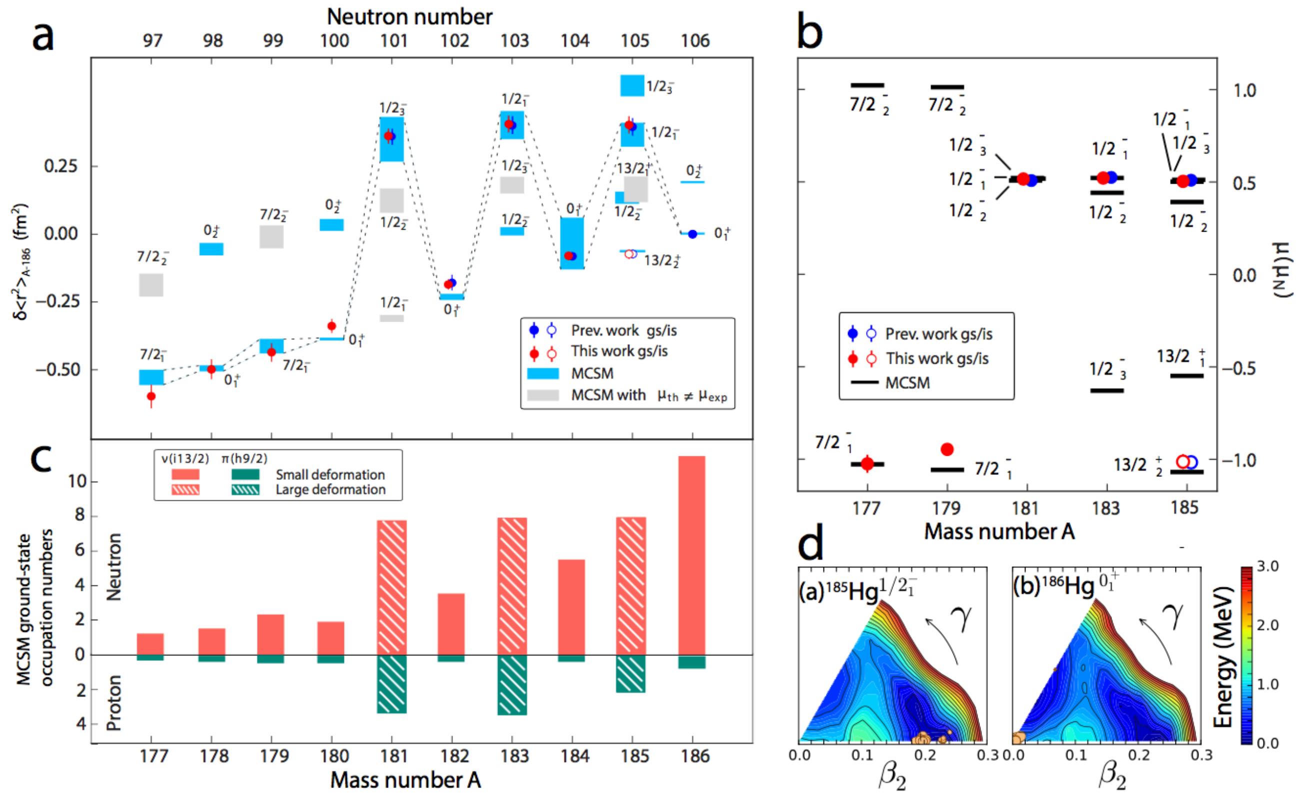

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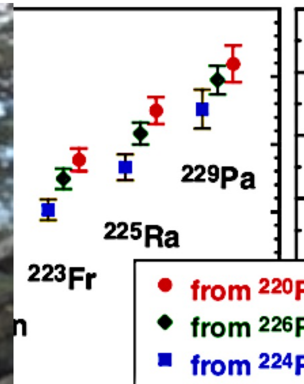
Correlating Schiff Moments in the Light Actinides with Octupole Moments

Jacek Dobaczewski,[1,2,3,4] Jonathan Engel,[5] Markus Kortelainen,[2,4] and Pierre Becker[1]
[1]*Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom*

$$S \approx -2\frac{\langle\Psi_0|\hat{S}_0|\bar{\Psi}_0\rangle\langle\bar{\Psi}_0|\hat{V}_{PT}|\Psi_0\rangle}{\Delta E}$$

PHYSICAL REVIEW LETTERS 121, 232501 (2018)



We show tha ctupole momen
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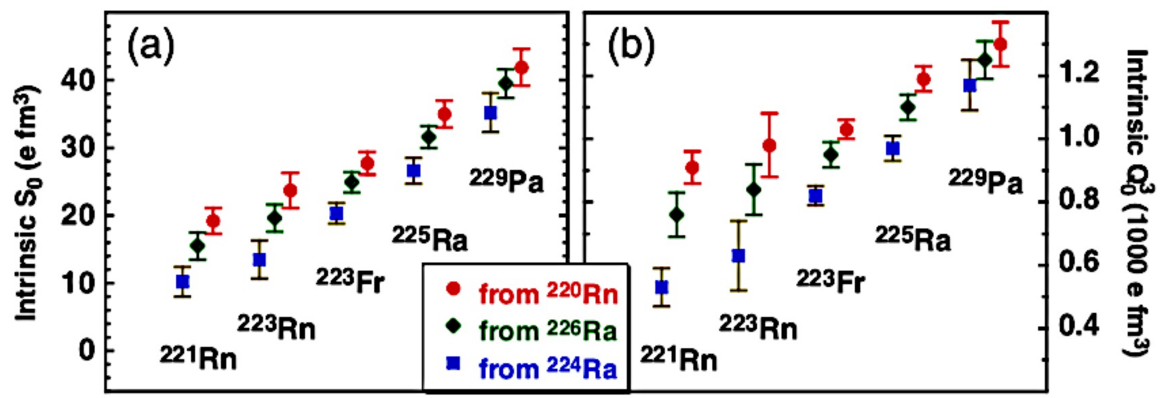
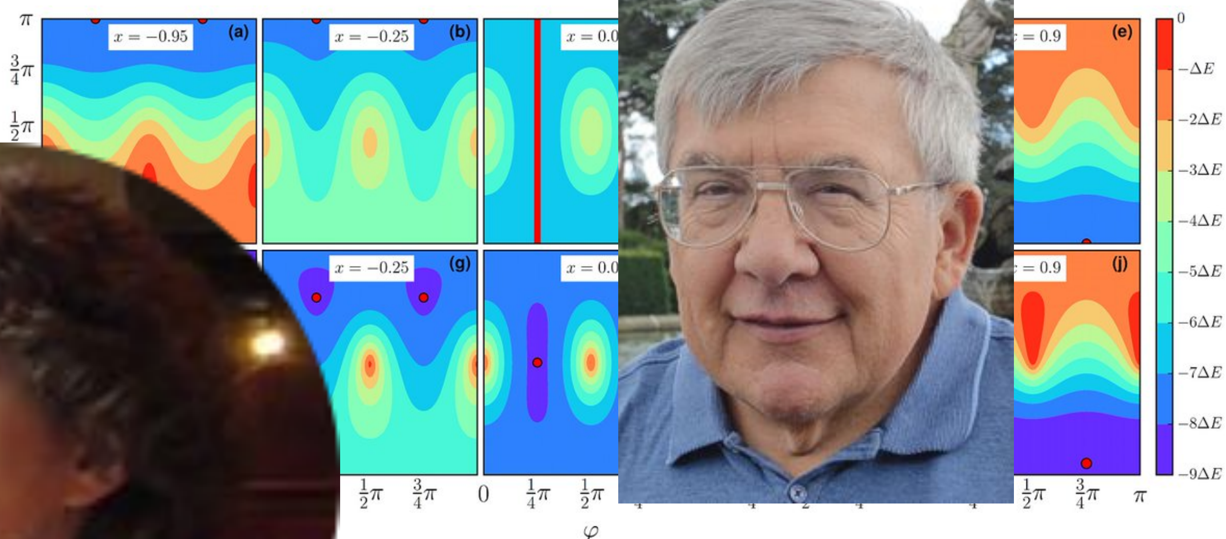


We show that the measured intrinsic octupole moments of 220Rn, 224Ra, and 226Ra constrain the intrinsic Schiff moments of 225Ra, 221Rn, 223Rn, 223Fr, 225Ra, and 229Pa. The result is a dramatically reduced uncertainty in intrinsic Schiff moments. Direct measurements of octupole moments in odd nuclei will reduce the uncertainty even more. **The only significant source of nuclear-physics error in the laboratory Schiff moments will then be the intrinsic matrix elements of the time-reversal noninvariant interaction produced by CP-violating fundamental physics**. Those matrix elements are also correlated with octupole moments, but with a larger systematic uncertainty.

Symmetry restoration in the nuclear-DFT description of proton-neutron pairing

A. Márquez Romero,[1] J. Dobaczewski,[1,2,3] and A. Pastore[1]

arXiv:1812.03927



… the SO(8) Hamiltonian calculated for the unprojected … d projected (lower panels) Thouless states …

$|Z\rangle = | \{ \sin(\frac{1}{2}\alpha)e^{-i\varphi}\hat{P}_0^{+}$ …

… rized by angles α and φ i… … $(\hat{P}_0^{+})$ and isoscalar $(\hat{D}_0^{+})$ isoaxial and axial pair…

“A tour-de-force variation-after-projection symmetry … applied simultaneously to particle-number, spin, and isospin … ates, which has never been realized up to now”. Comparison with exa… …hat the precision is better than 1.5%. The paper resolves a 50-odd years … …ng that the pair-condensate and quartet-condensate pictures are equ…

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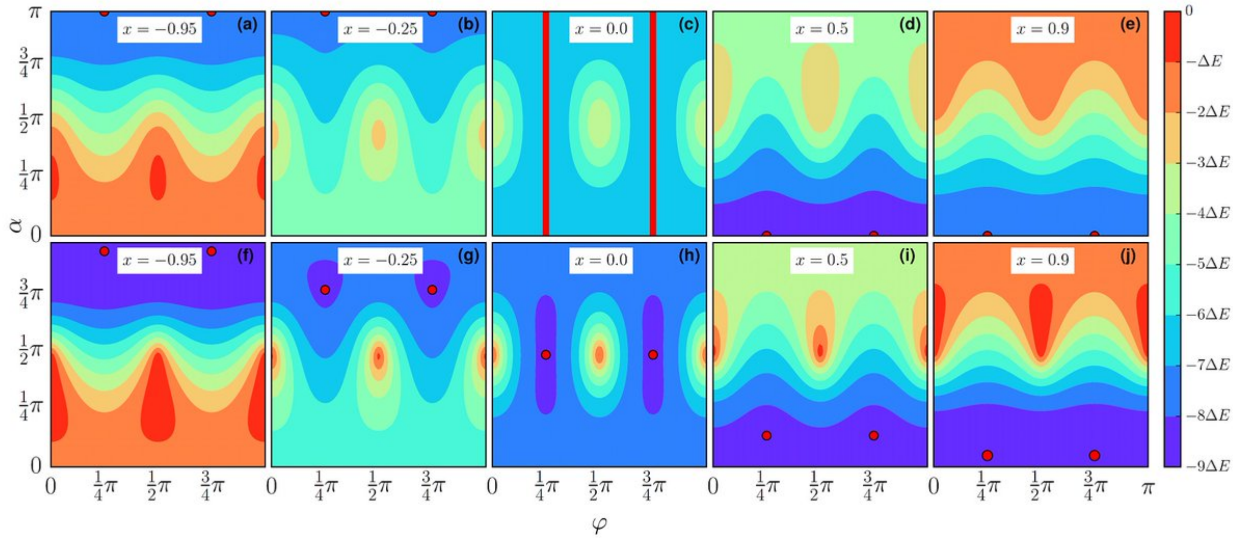


Average values of the SO(8) Hamiltonian calculated for the unprojected (upper panels) and projected (lower panels) Thouless states,

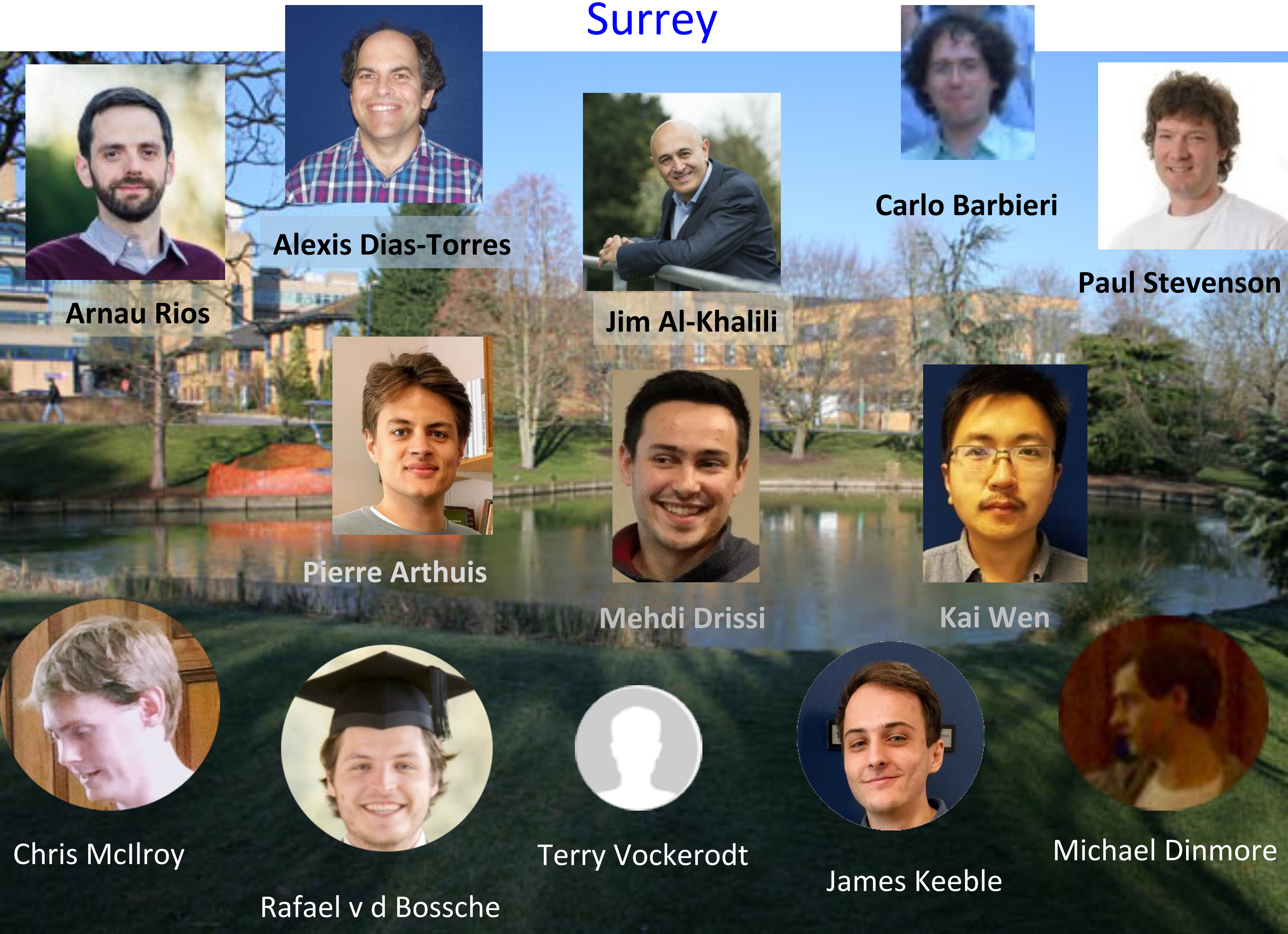
$$|Z\rangle = |\left\{\sin(\tfrac{1}{2}\alpha)e^{-i\varphi}\hat{P}_0^+ + \cos(\tfrac{1}{2}\alpha)e^{i\varphi}\hat{D}_0^+\right\}|0\rangle,$$

parametrized by angles α and φ in terms of the isovector ($\hat{P}_0^+$) and isoscalar ($\hat{D}_0^+$) isoaxial and axial pairs.

“A tour-de-force variation-after-projection symmetry-restoration method applied simultaneously to particle-number, spin, and isospin symmetry-broken states, which has never been realized up to now”. Comparison with exact solutions shows that the precision is better than 1.5%. The paper resolves a 50-odd years old dispute by showing that the pair-condensate and quartet-condensate pictures are equivalent.

Surrey

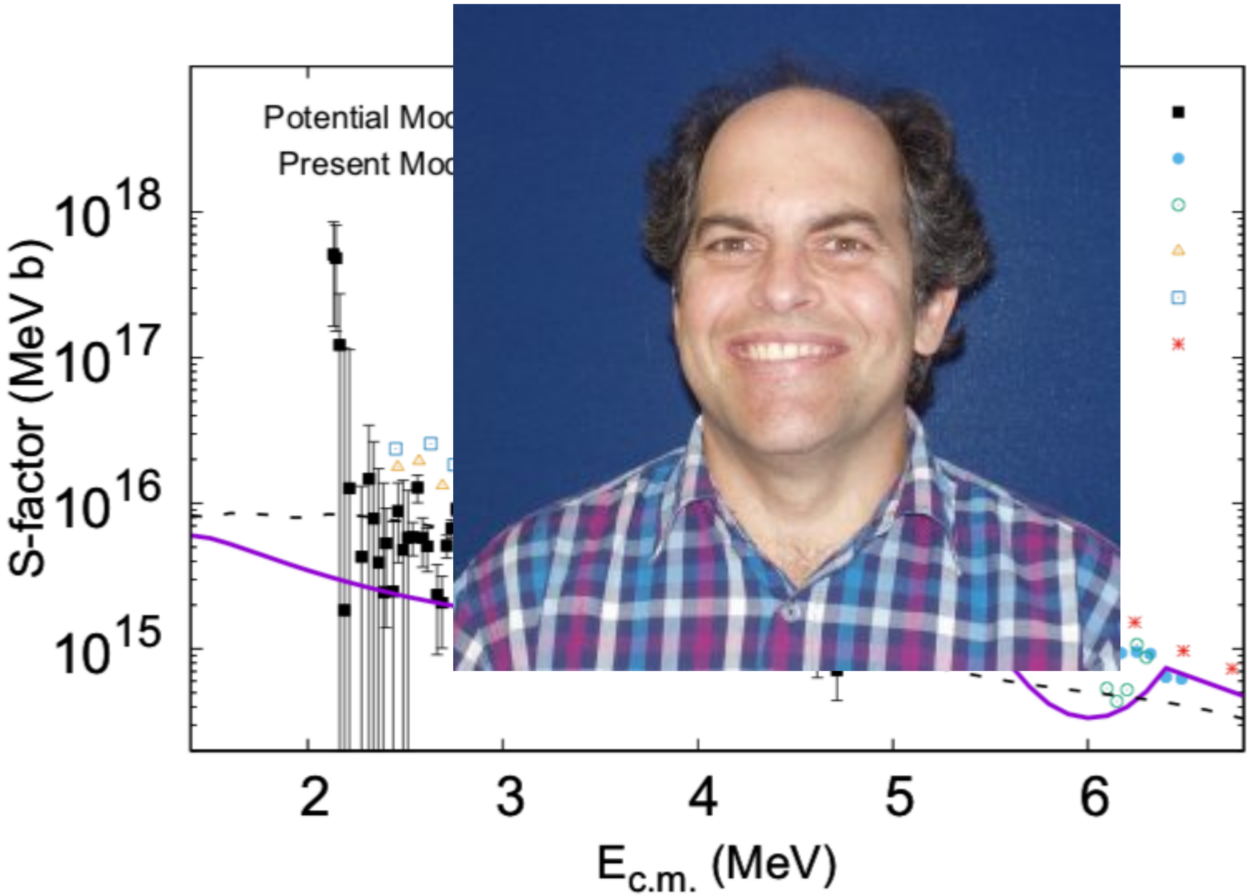
Surrey


Alexis Dias-Torres
Carlo Barbieri
Arnau Rios
Jim Al-Khalili
Paul Stevenson
Pierre Arthuis
Mehdi Drissi
Kai Wen
Chris McIlroy
Terry Vockerodt
Michael Dinmore
James Keeble
Rafael v d Bossche

Characterizing the astrophysical S factor for $^{12}C + ^{12}C$ fusion with wave-packet dynamics

Alexis Diaz-Torres[1,*] and Michael Wiescher[2]
[1]Department of Physics, University of Surrey, Guildford GU2 7XH, United Kingdom

PHYSICAL REVIEW C 97, 055802 (2018)



Work using wave packet dynamics explains some resonant structures in the astrophysical S-factor, suggesting that the origin of other observed resonances may be connected with other (not ^{12}C+^{12}C) molecular configurations in ^{24}Mg.

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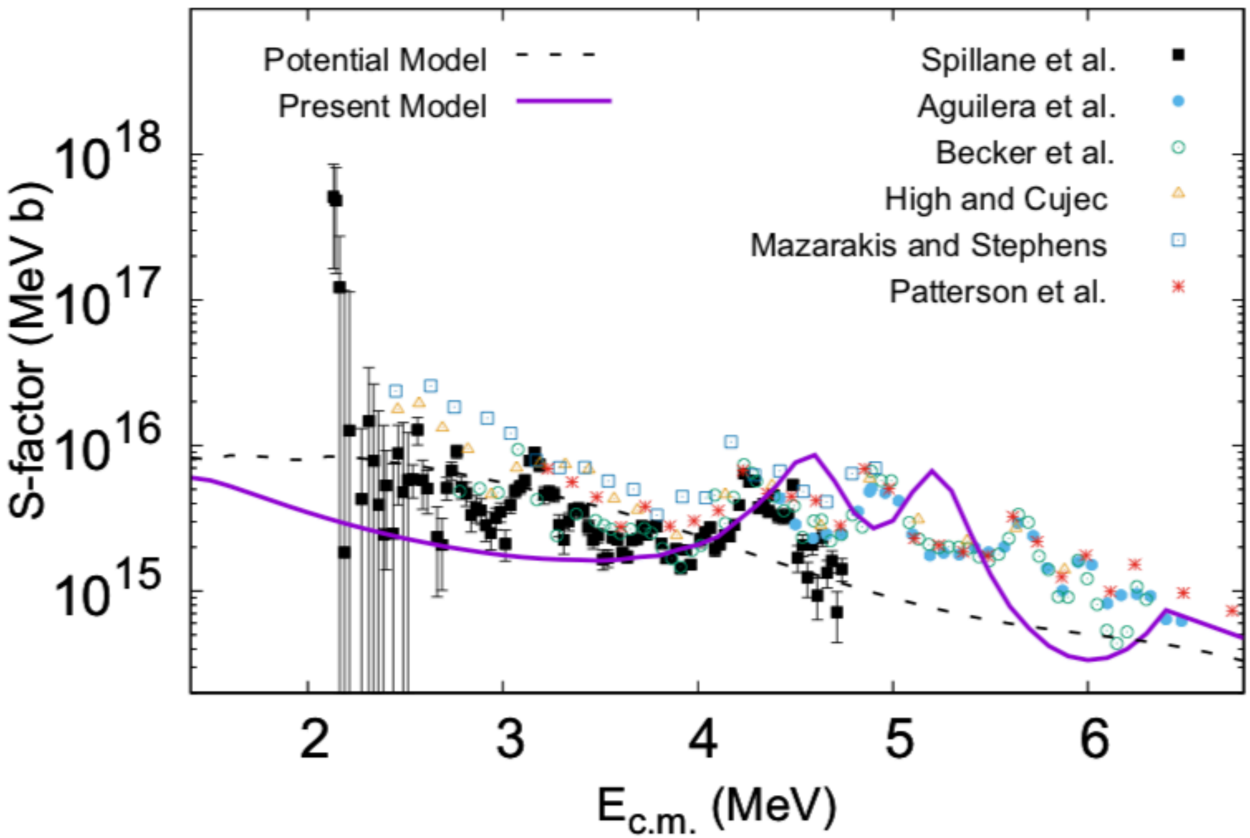

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Reduced sensitivity of the (*d*, *p*) cross sections to the deuteron model beyond the adiabatic approximation

M. Gómez-Ramos[1] and N. K. Timofeyuk[2]

PHYSICAL REVIEW C 98, 011601(R) (2018)

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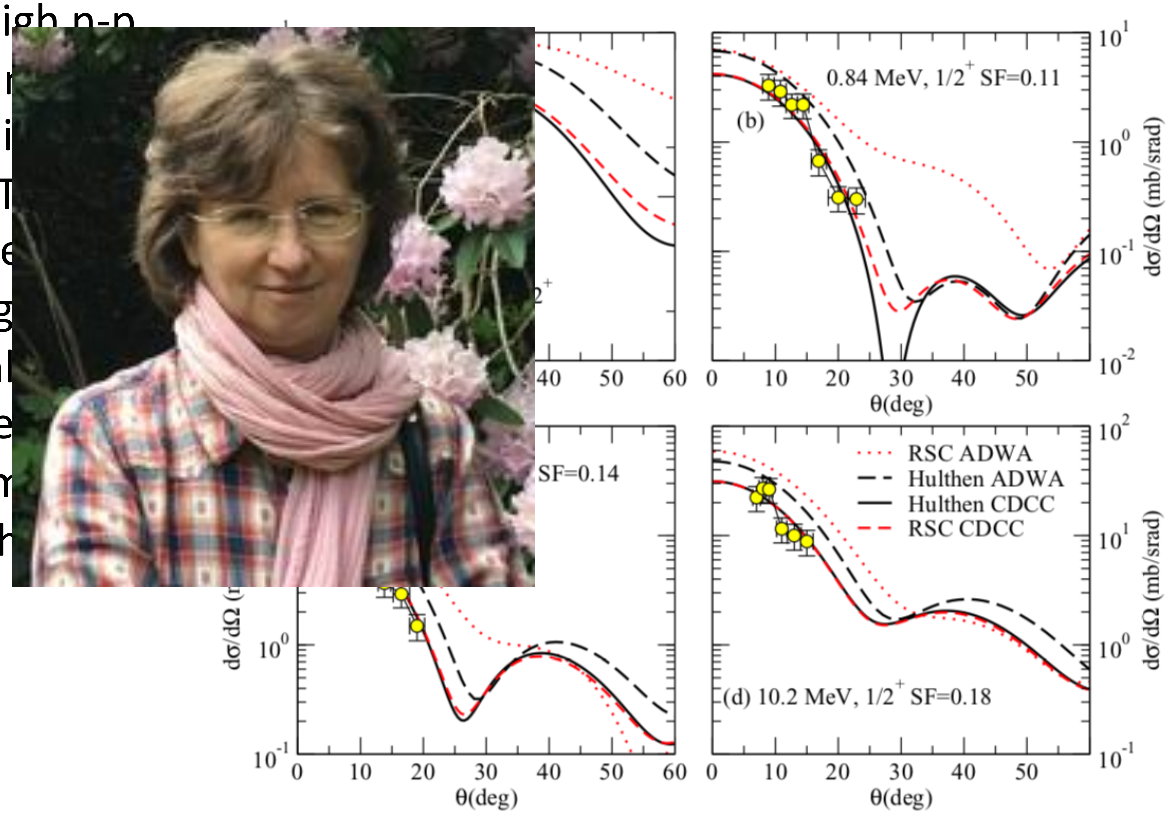

FIG. 1. Differential cross sections of ^{26m}Al$(d,p)^{27}$Al at $E_d^{lab} = 9.2$ MeV for population of the ^{27}Al$(5/2^+)$ ground state and the excited $1/2^+$ states at $E_x = 0.84$, 6.8, and 10.2 MeV.

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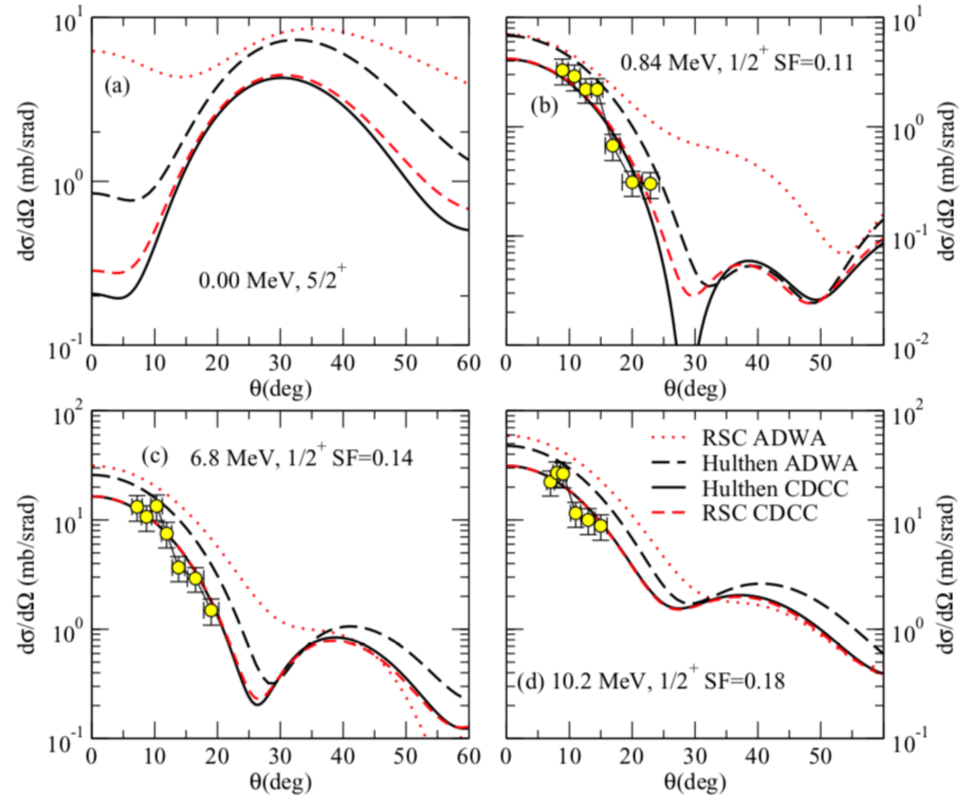
Our calculations reveal a significant reduction of the sensitivity to the high n-p momenta thus confirming that it is mostly associated with theoretical uncertainties of the adiabatic approximation itself. The nonadiabatic effects in the presence of nonlocality were found to be stronger than those in the case of the local optical potentials. These results argue for extending the analysis of the (d,p) reactions, measured for spectroscopic studies, beyond the adiabatic approximation.



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Inclusive electron-nucleus cross section within the self-consistent Green's function approach

N. Rocco and C. Barbieri

PHYSICAL REVIEW C 98, 025501 (2018)

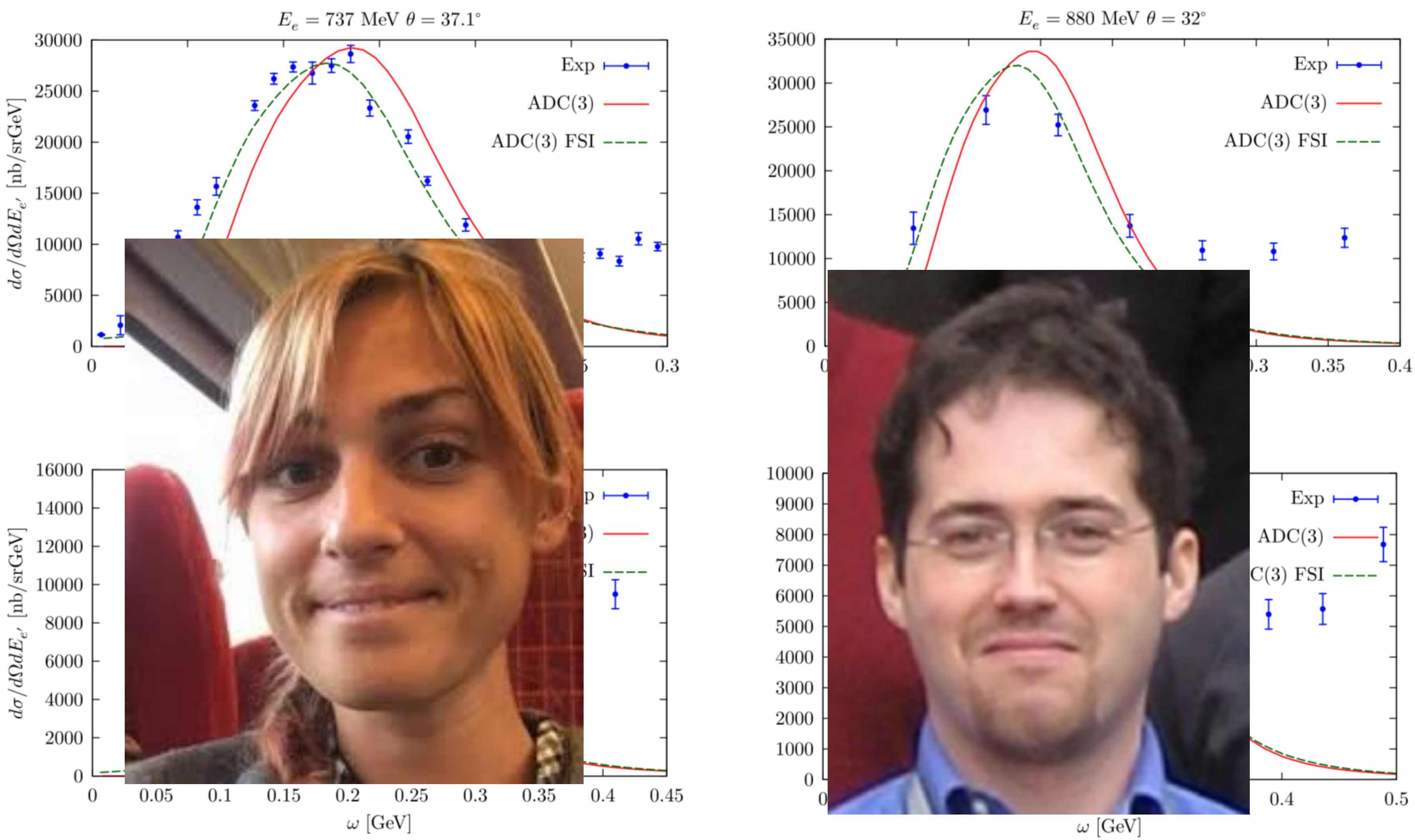

FIG. 11. Double-differential electron-^{16}O cross sections for different values of incident electron energy and scattering angle. The solid (red) line corresponds to the SCGF-ADC(3) results and the dashed (green) one has been obtained by including FSI corrections. The experimental data are taken from Ref. [49].

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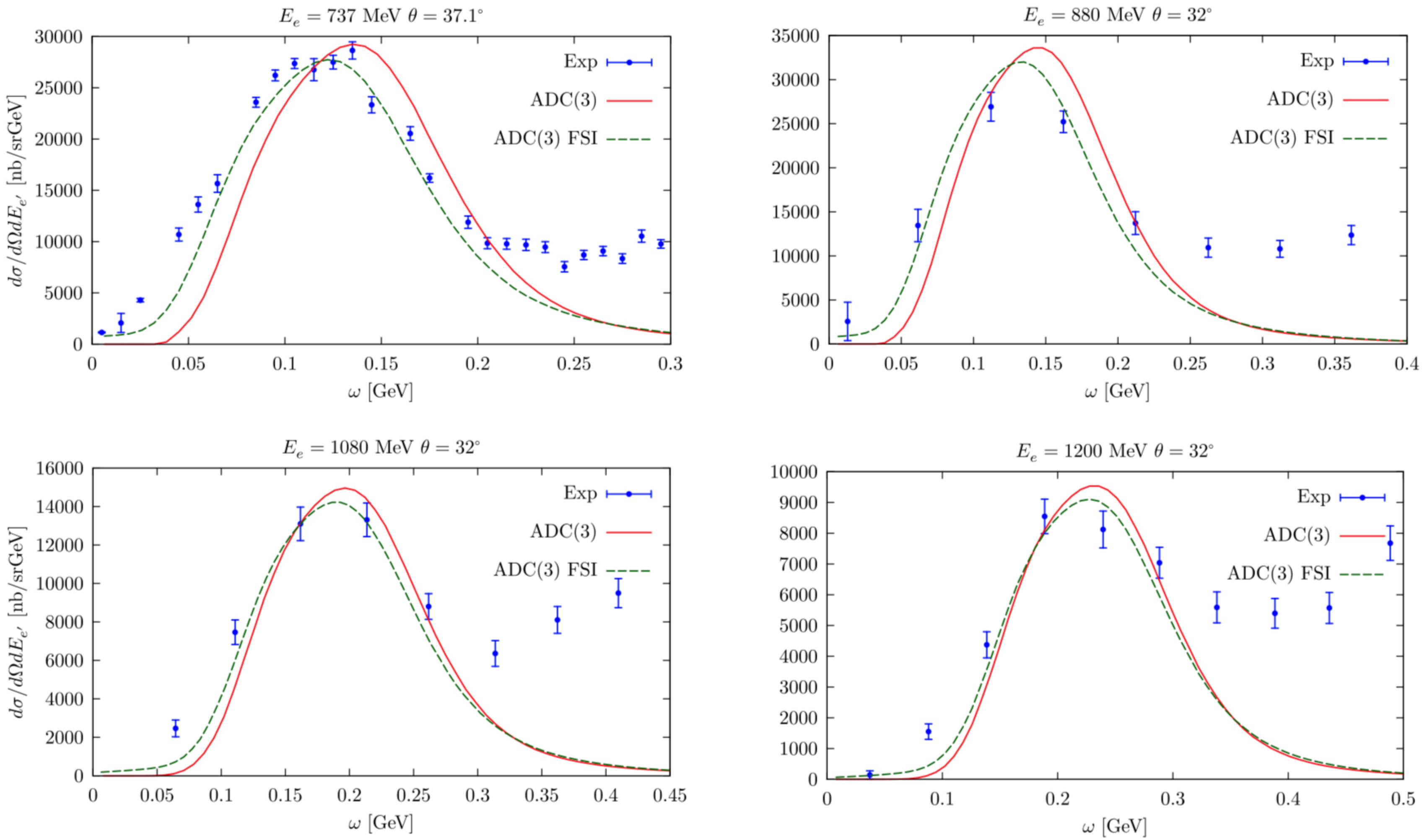

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Doubly magic nuclei from lattice QCD forces at $M_{PS} = 469$ MeV/ c^2

C. McIlroy,[1,*] C. Barbieri,[1,†] T. Inoue,[2,3] T. Doi,[3,4] and T. Hatsuda[3,4]
[1]Department of Physics, University of Surrey, Guildford GU2 7XH, United Kingdom

PHYSICAL REVIEW C 97, 021303(R) (2018)

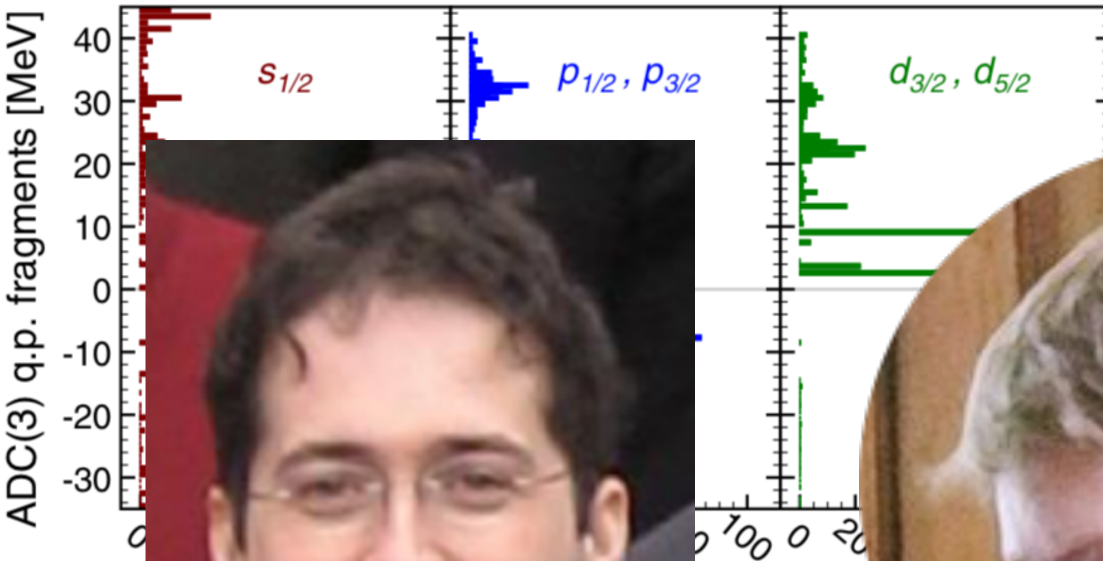

FIG. 4 … th distribution
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approach… aves of different an…

The results suggest an interesting possible behavior in which nuclei are unbound at very large pion masses and islands of stability appear at first around the traditional doubly magic numbers when the pion mass is lowered toward its physical value. The calculated one-nucleon spectral distributions are qualitatively close to those of real nuclei even for the pseudoscalar meson mass considered here.

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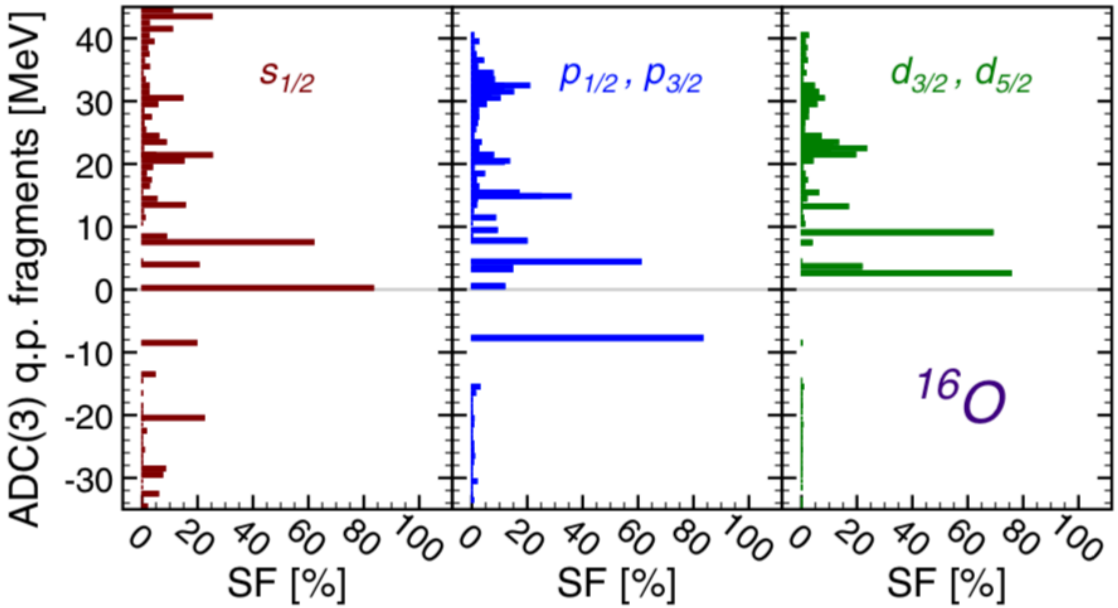

PHYSICAL REVIEW C 97, 021303(R) (2018)

FIG. 4. Single-particle spectral strength distribution of ^{16}O obtained from the dressed propagator in the full $T^{\mathrm{BGE}}(\omega)$ plus ADC(3) approach. Each panel displays partial waves of different angular

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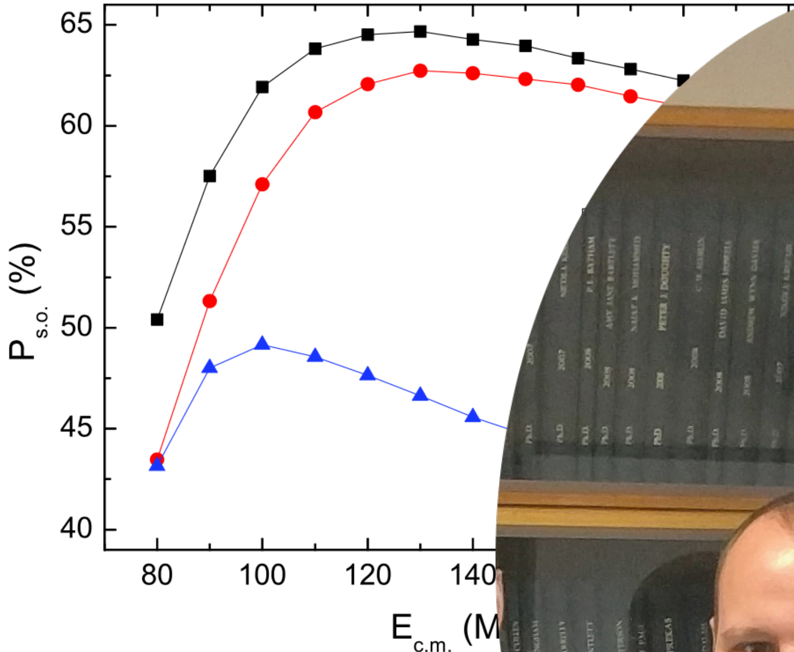
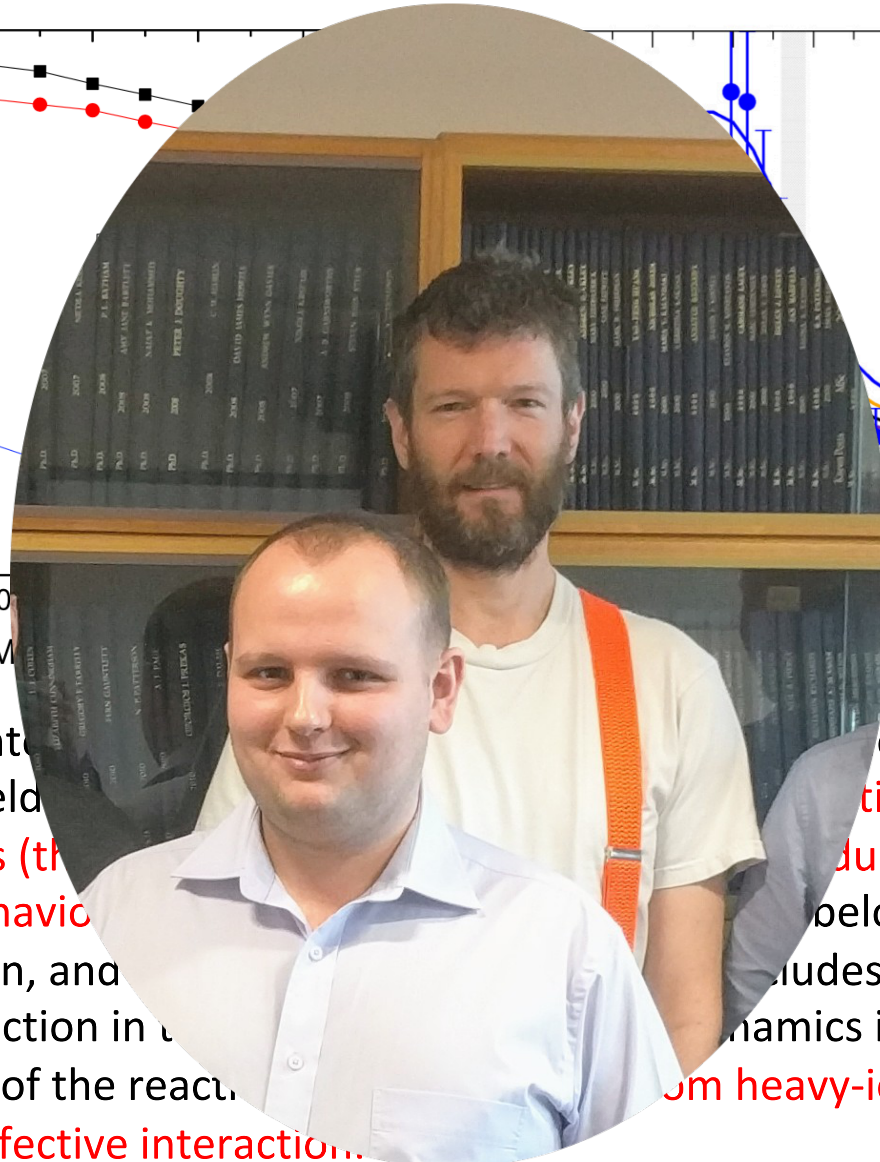
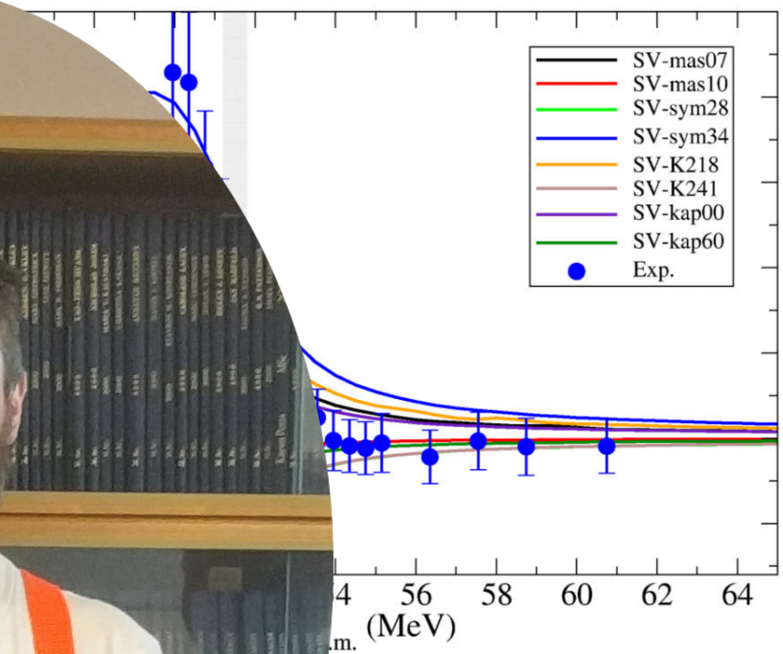
Low-energy heavy-ion reactions and the Skyrme effective interaction

P.D. Stevenson *, M.C. Barton

Progress in Particle and Nuclear Physics 104 (2019) 142–164







The role of the effective int… ons has been surveyed. Within mean-field… tive interaction between reasonable limits (th… duce qualitatively and quantitatively variable behavio… below the Coulomb barrier, in the fusion region, and… ludes, therefore, that the role of the effective interaction in t… namics is instrumental in understanding the details of the react… om heavy-ion reactions inform us about the details of the effective interaction.

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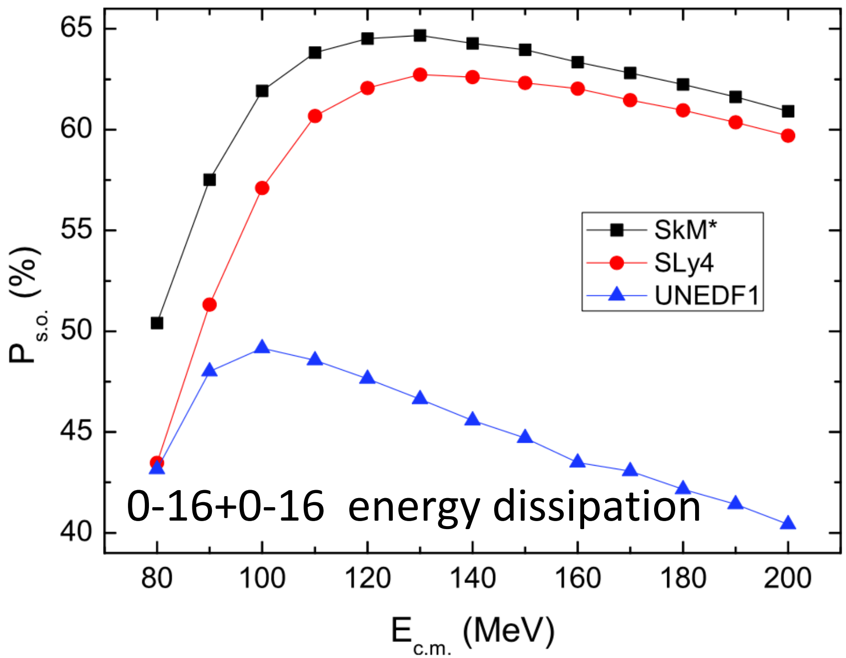

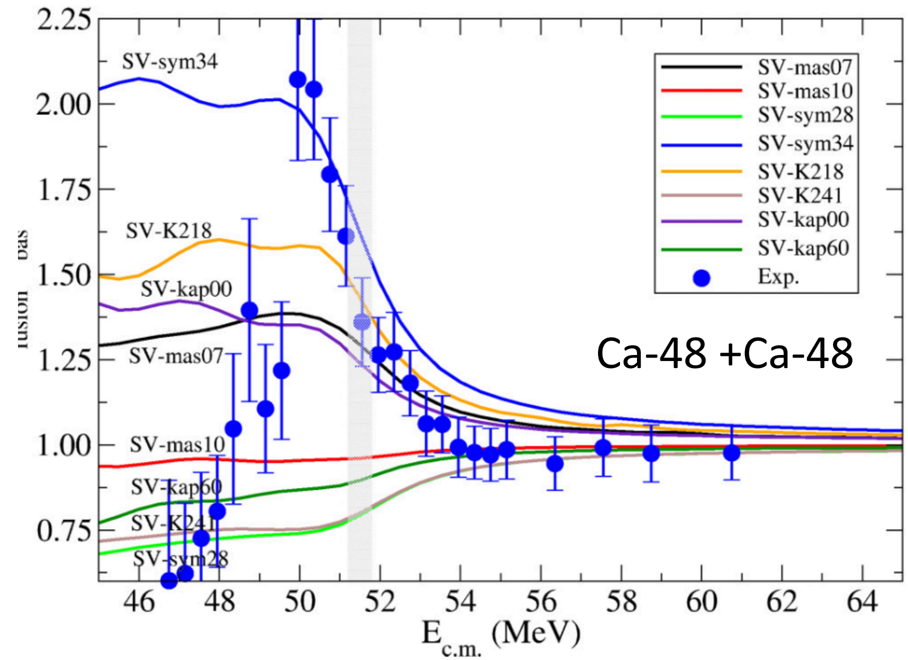

The role of the effective interaction in the dynamics of heavy-ion reactions has been surveyed. Within mean-field dynamics, the effects of varying the effective interaction between reasonable limits (those that fit ground state data well) produce qualitatively and quantitatively variable behaviour in heavy-ion collisions at energies below the Coulomb barrier, in the fusion region, and in the deep-inelastic …. One concludes, therefore, that the role of the effective interaction in the calculation of reaction dynamics is instrumental in understanding the details of the reaction, and that results from heavy-ion reactions inform us about the details of the effective interaction.

Two-body dissipation effect in nuclear fusion reactions

Kai Wen,* M. C. Barton, Arnau Rios, and P. D. Stevenson

PHYSICAL REVIEW C 98, 014603 (2018)

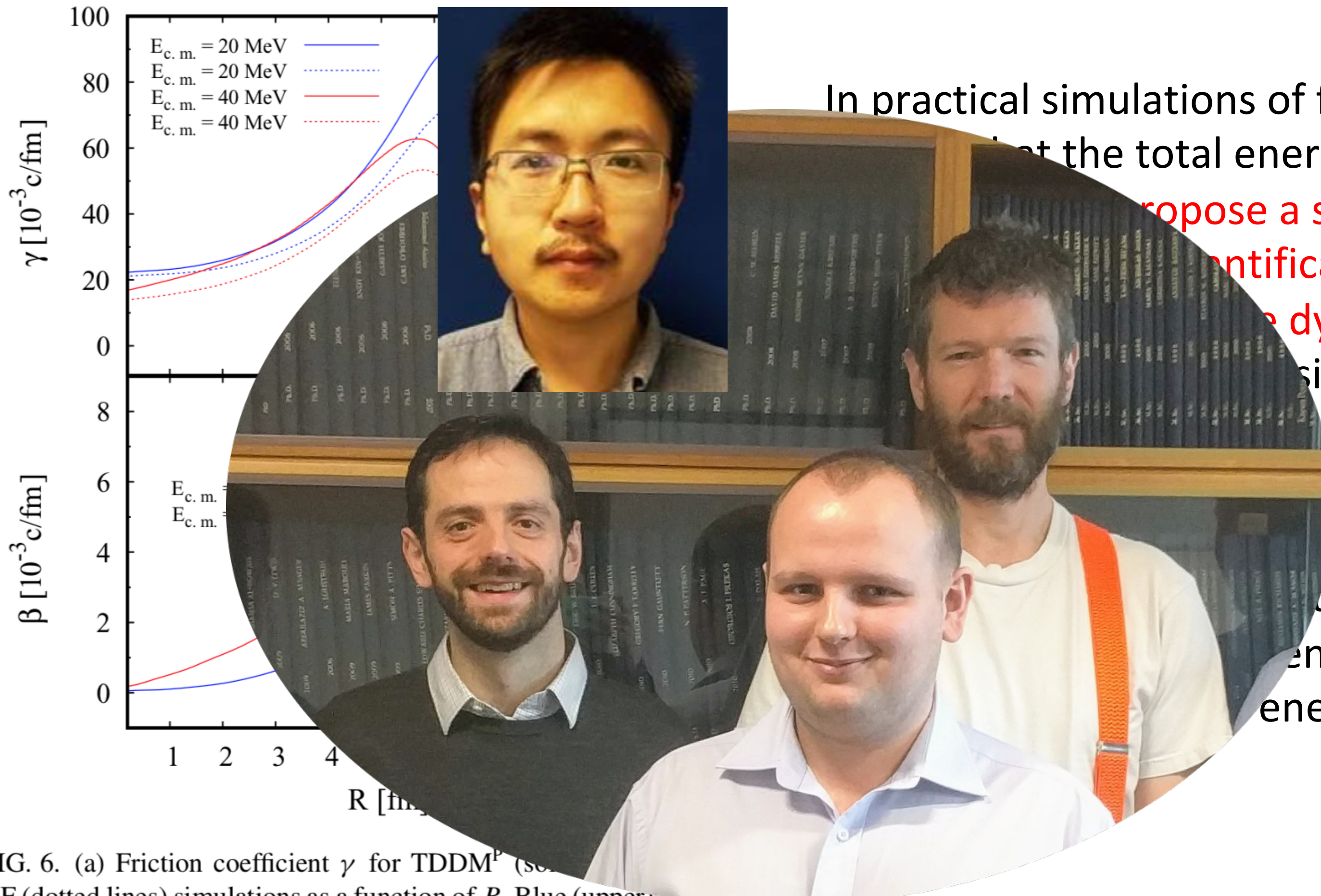

FIG. 6. (a) Friction coefficient γ for TDDM^{P} (so... TDHF (dotted lines) simulations as a function of R. Blue (upper) and red (lower) lines indicate the results at incident energies of $E_{c.m.}$ = 20 MeV and $E_{c.m.}$ = 40 MeV, respectively. (b) β parameters in the same conditions.

In practical simulations of fusion reactions
t the total energy is not
ropose a solution that
ntification of
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Two-body dissipation effect in nuclear fusion reactions

PHYSICAL REVIEW C 98, 014603 (2018)

Kai Wen,* M. C. Barton, Arnau Rios, and P. D. Stevenson

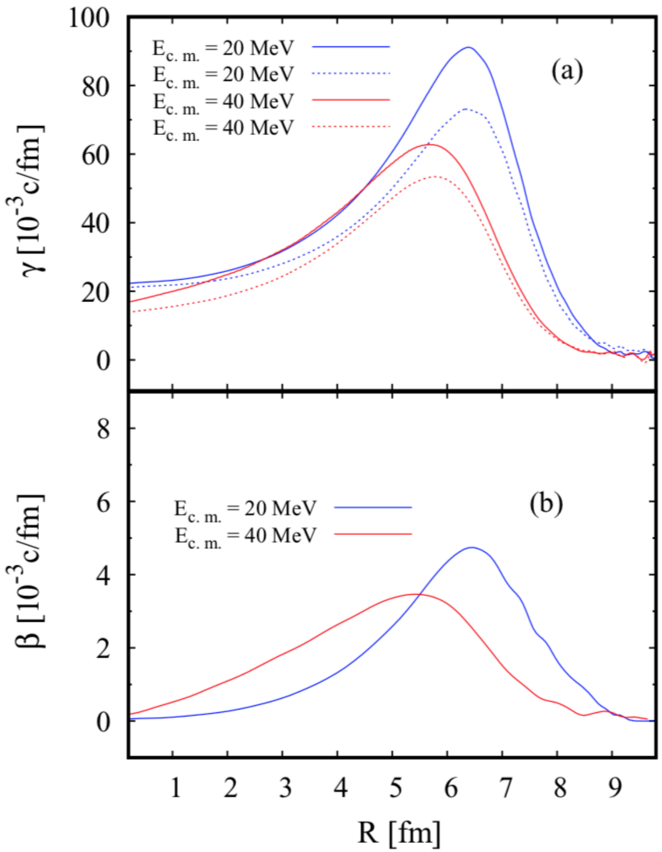


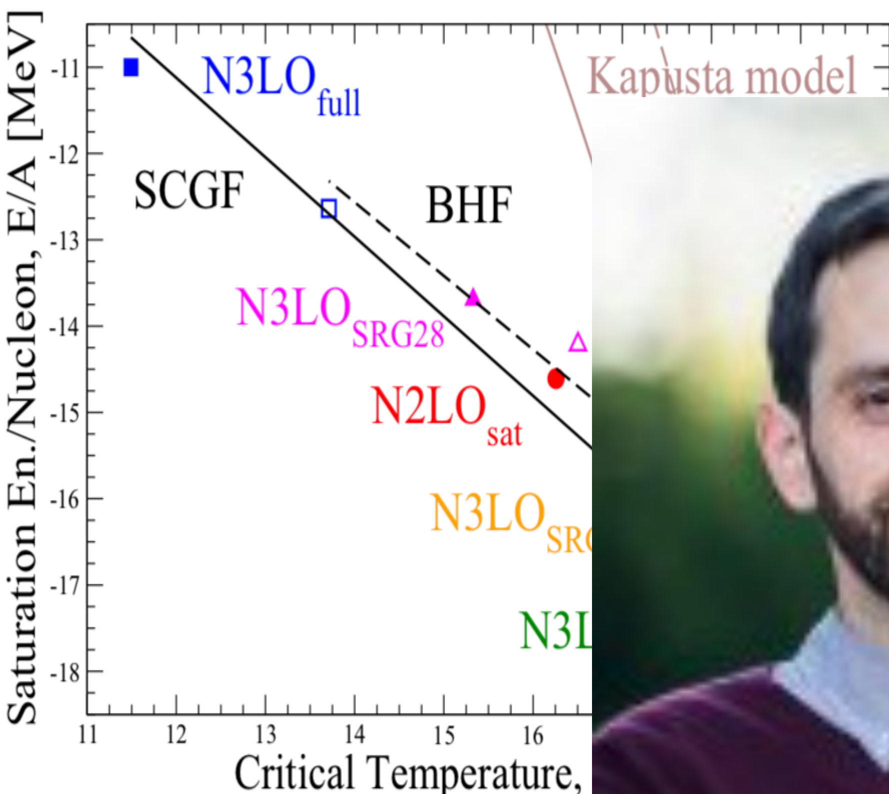
FIG. 6. (a) Friction coefficient γ for TDDM^{P} (solid lines) and TDHF (dotted lines) simulations as a function of R. Blue (upper) and red (lower) lines indicate the results at incident energies of $E_{c.m.}$ = 20 MeV and $E_{c.m.}$ = 40 MeV, respectively. (b) β parameters in the same conditions.

In practical simulations of fusion reactions we find that the total energy is not conserved. We propose a solution that allows for a clear quantification of dissipative effects in the dynamics. Compared to mean-field simulations, friction coefficients in the density-matrix approach are enhanced by about 20%. An energy dependence of the dissipative mechanism is also demonstrated, indicating that two-body collisions are more efficient at generating friction at low incident energies.

Microscopic predictions of the nuclear matter liquid-gas phase transition

Arianna Carbone,[1,*] Artur Polls,[2,†] and Arnau Rios[3,‡]

PHYSICAL REVIEW C 98, 025804 (2018)



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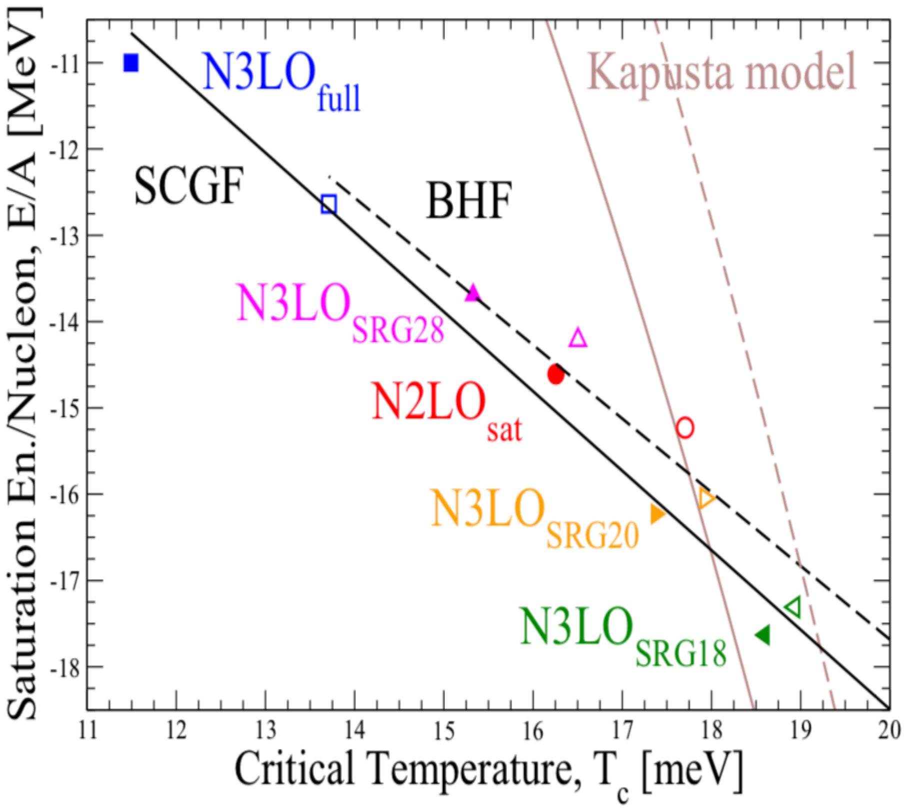

We find that systematics due to Hamiltonians dominate over many-body uncertainties. Based on this wide pool of calculations, we estimate that the critical temperature is 16±2MeV, in reasonable agreement with experimental results. We also find that there is a strong correlation between the critical temperature and the saturation energy in microscopic many-body simulations.

Manchester

Manchester


Niels Walet
Judith McGovern
Mike Birse
Johannes Kirscher
Alex Moore
Felipe Isaule

Application of the functional renormalization group to Bose gases: From linear to hydrodynamic fluctuations

PHYSICAL REVIEW B 98, 144502 (2018)

Felipe Isaule, Michael C. Birse, and Niels R. Walet

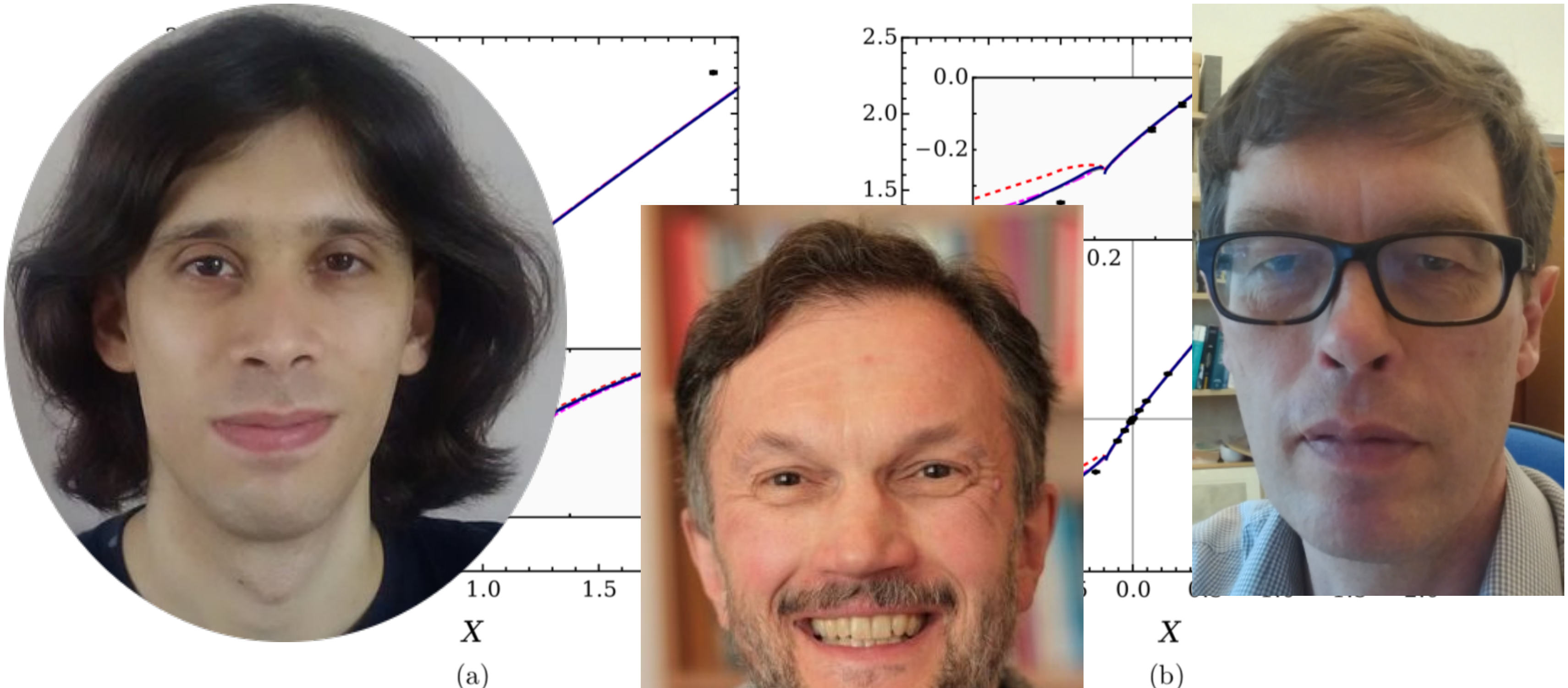

FIG. 7. Dimensionless superfluid density f_s (a) and den… in two dimensions. The point where $X = 0$ in the FRG calculations was chosen when $f_s = 2/\pi$. The fuch… sing $\nu = 1.5$, the red dotted lines using $\nu = 2$, the gray dashed lines using $\nu = 2.5$, and the solid dark blue … correspond to the MC simulations of Ref. [51].

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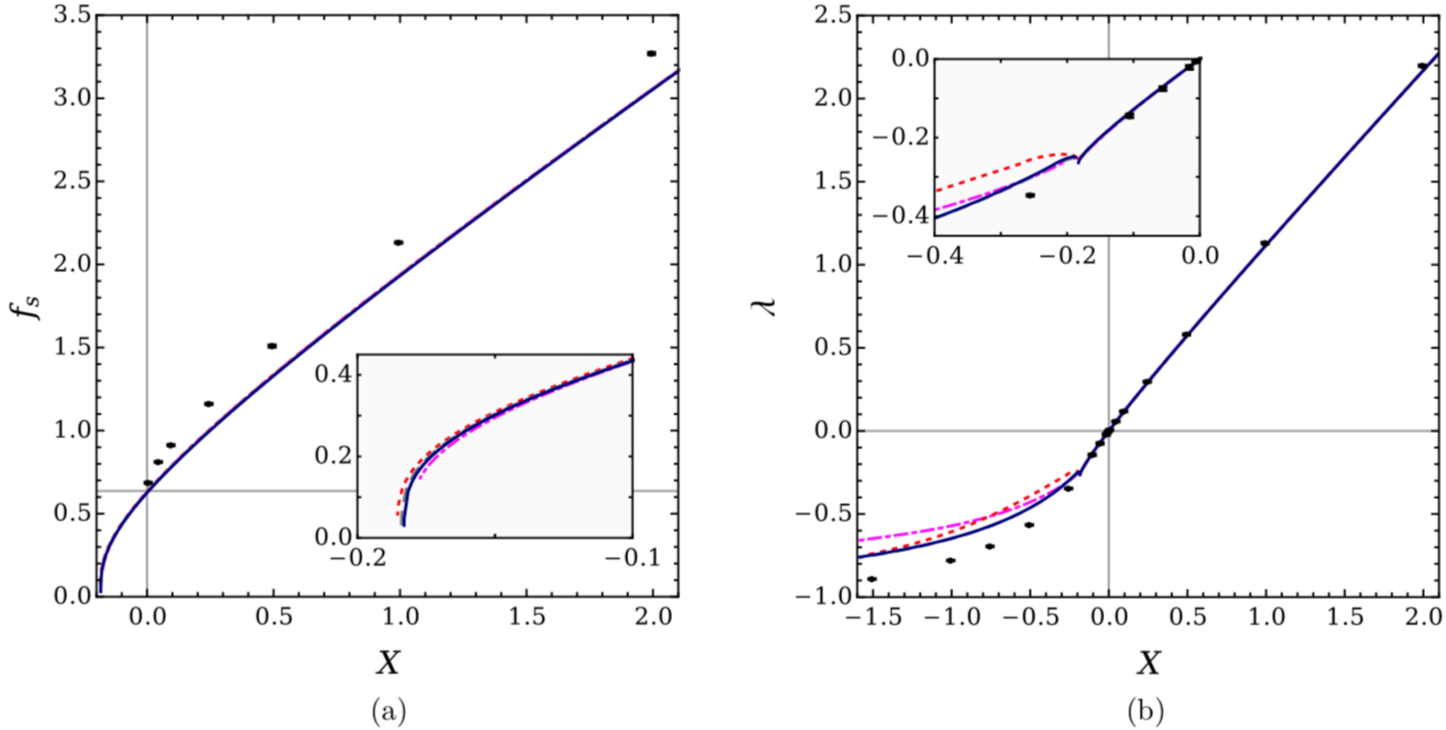
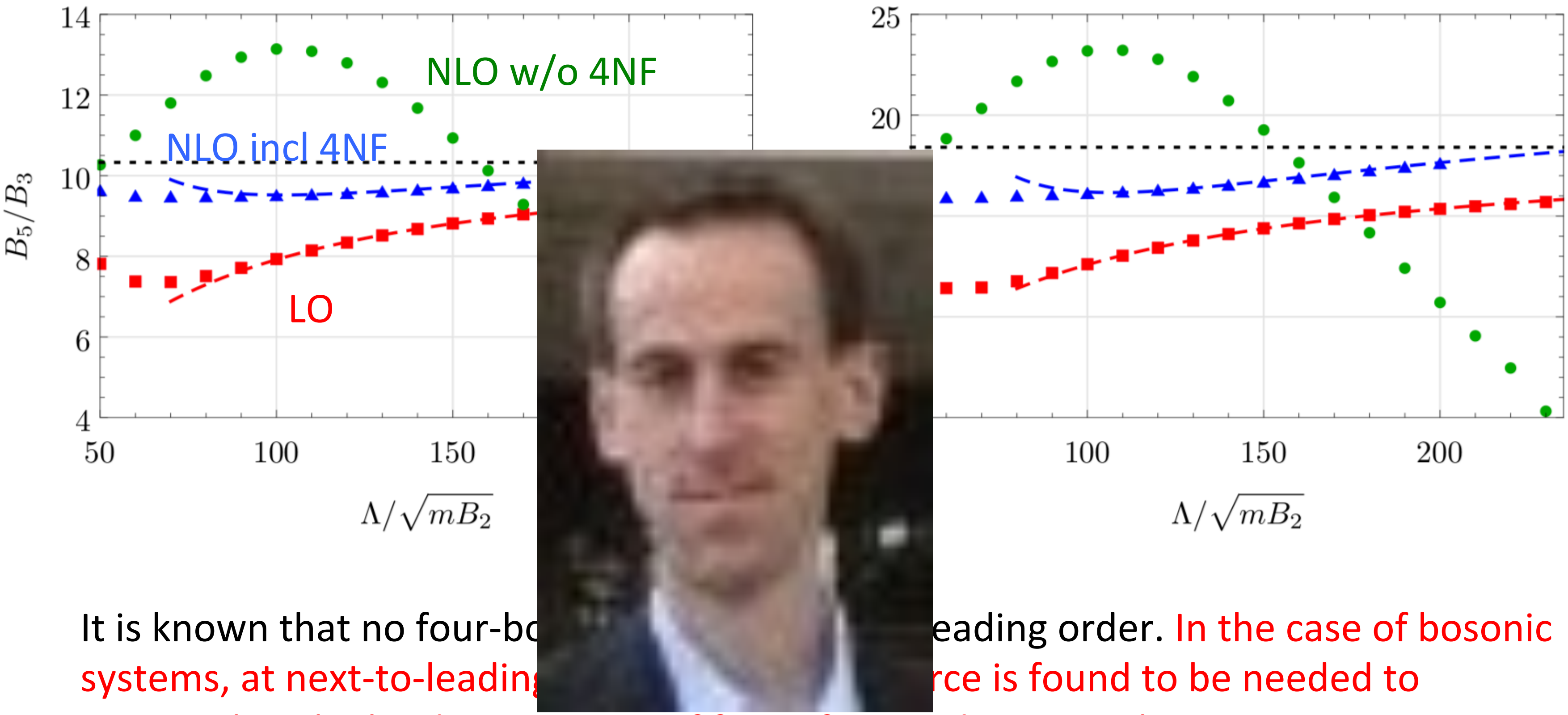


FIG. 7. Dimensionless superfluid density f_s (a) and density profile λ (b) as a function of X in two dimensions. The point where $X = 0$ in the FRG calculations was chosen when $f_s = 2/\pi$. The fuchsia dash-dotted lines are obtained using $\nu = 1.5$, the red dotted lines using $\nu = 2$, the gray dashed lines using $\nu = 2.5$, and the solid dark blue lines using $\nu = 3$. The black circles correspond to the MC simulations of Ref. [51].

An improved approach has been developed for treating Goldstone fluctuations in the functional renormalisation group. This has been applied to superlfuids in two and three dimensions, and it gives results that agree well with Monte-Carlo simulations

The four-body scale in universal few-boson systems

B. Bazak,[1] J. Kirscher,[2,3] S. König,[4,5] M. Pavón Valderrama,[6] N. Barnea,[1] and U. van Kolck[7,8]



It is known that no four-bo eading order. In the case of bosonic systems, at next-to-leadin rce is found to be needed to renormalise the binding energies of four-, five- and six-particle systems

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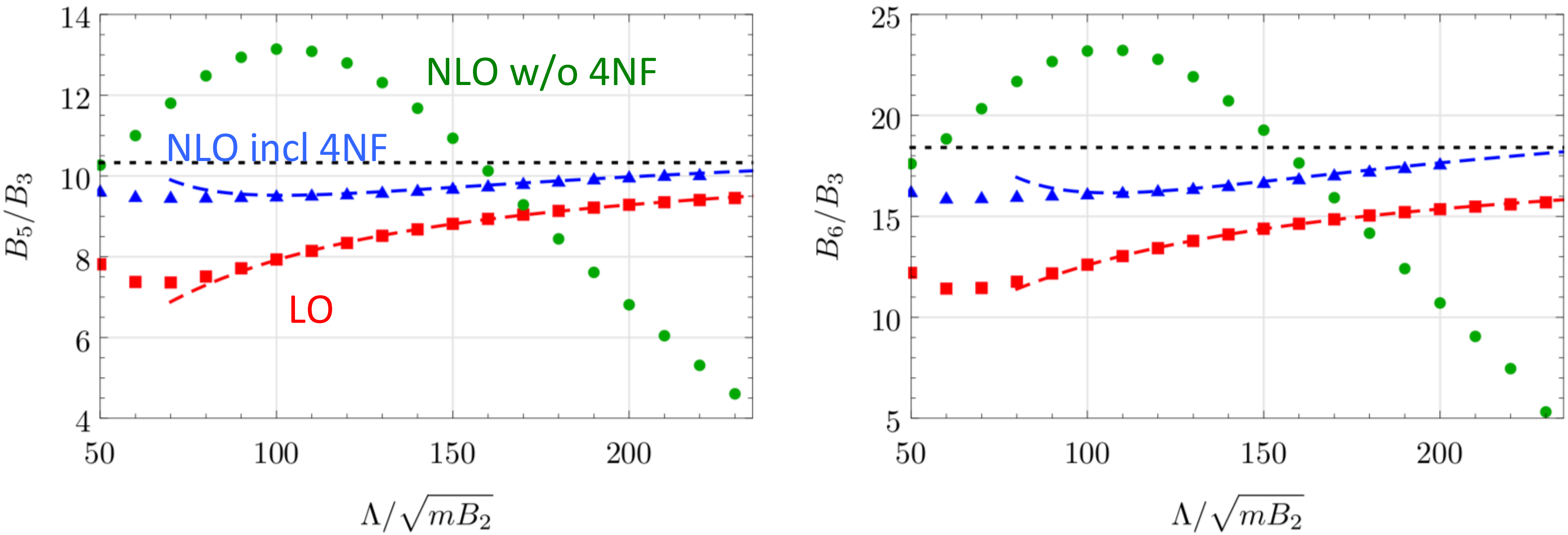

It is known that no four-body force is needed at leading order. In the case of bosonic systems, at next-to-leading order, a four-body force is found to be needed to renormalise the binding energies of four-, five- and six-particle systems

Renormalisation group analysis of electromagnetic couplings in the pionless effective field theory

A.N. Kvinikhidze[1] and M.C. Birse[2,a]

Eur. Phys. J. A (2018) 54: 216

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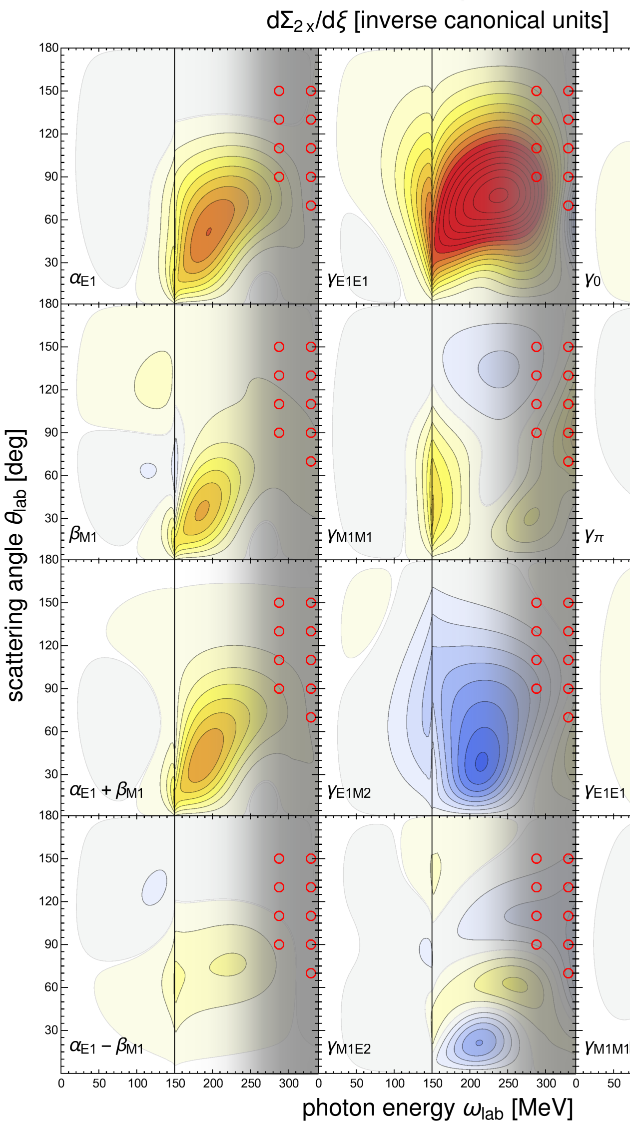
The general strucure of the two-body current in the pionless effective field theory has been analysed using the Wilsonian renormalisation group. A fixed point corresponding to the unitary limit was idenitfied. The scaling behaviour of perturbations around this point was used to determine the power counting for terms in the current and their contributions to the charge form factor.

Comprehensive study of observables in Compton scattering on the nucleon*

Eur. Phys. J. A (2018) 54: 37

Harald W. Grießhammer[1,a], Judith A. McGovern[2,b], and Daniel R. Phillips[3,c]



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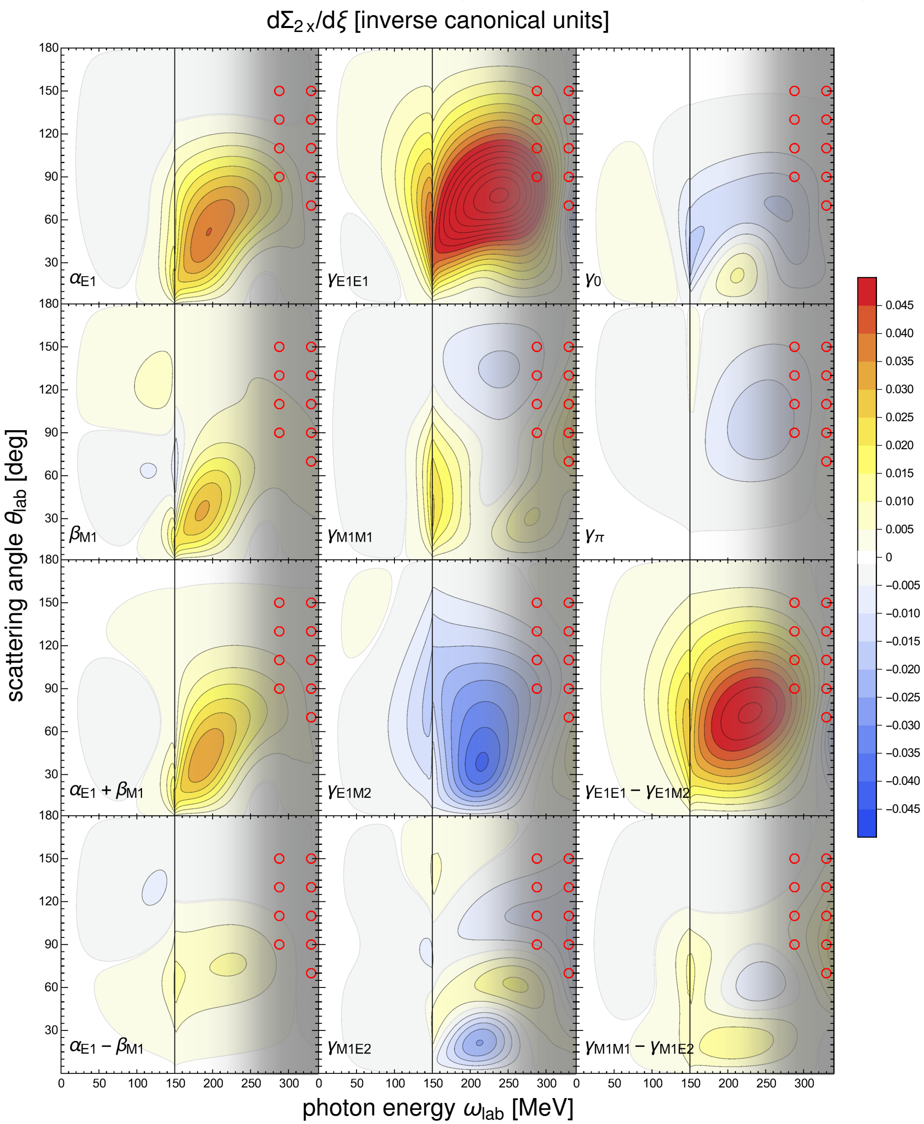
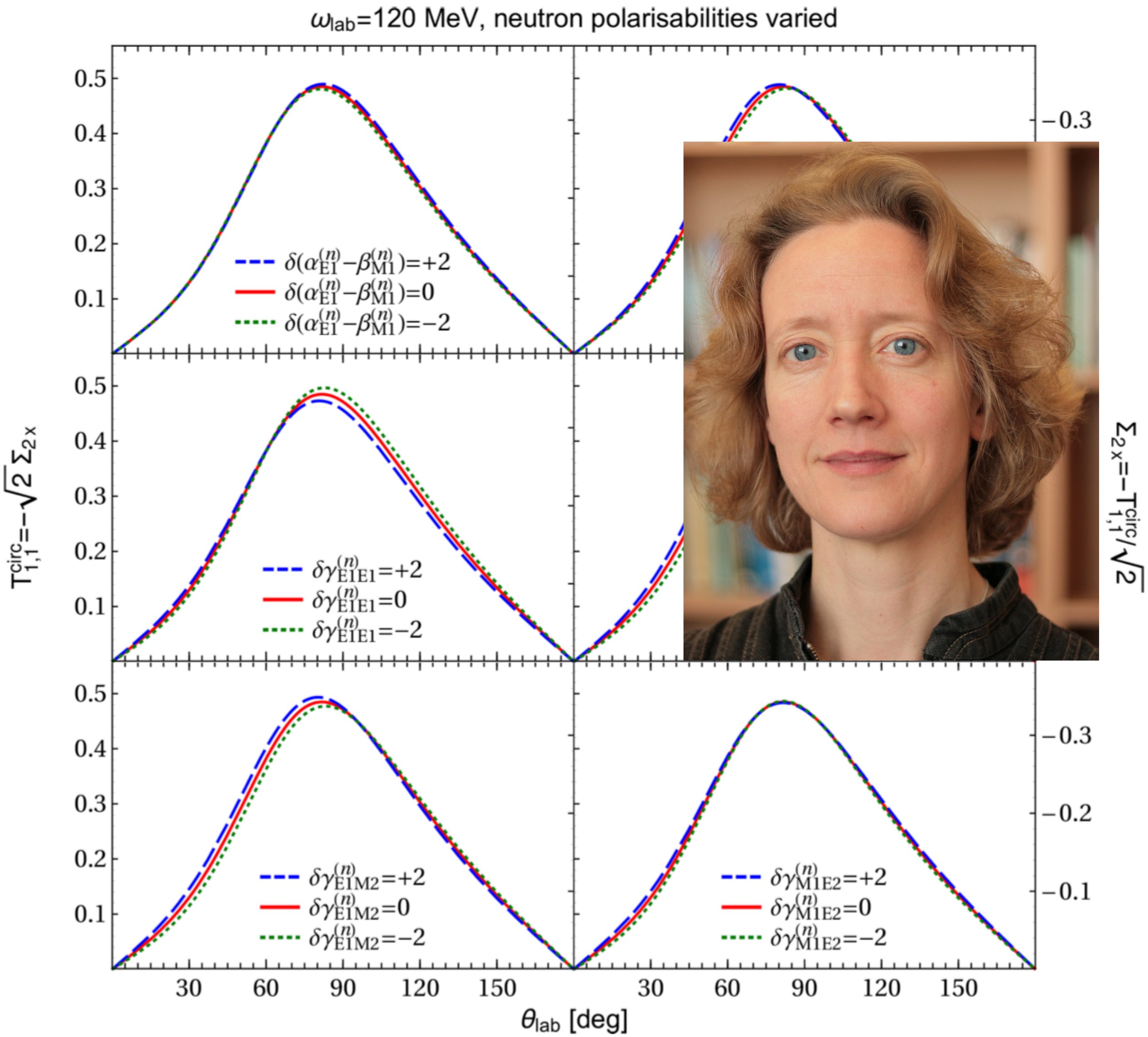


We present an analysis of 13 observables in Compton scattering on the proton. Cross sections, asymmetries with polarised beam and/or targets, and polarisation-transfer observables are investigated for energies up to the Δ(1232) resonance to determine their sensitivity to the proton's dipole scalar and spin polarisabilities. We find that for energies from pion-production threshold to about 250 MeV, multiple asymmetries have significant sensitivity to presently ill-determined combinations of proton spin polarisabilities. We also argue that the broad outcomes of this analysis will be replicated in complementary theoretical approaches, e.g., dispersion relations.

Elastic Compton scattering from ^{3}He and the role of the Delta

Arman Margaryan[1,a], Bruno Strandberg[2,3,b], Harald W. Grießhammer[4,c], Judith A. McGovern[5,d], Daniel R. Phillips[6,e], and Deepshikha Shukla[7,f]



Eur. Phys. J. A (2018) 54: 125

As the spin of polarised 3He is predominantly carried by its constituent neutron, elastic Compton scattering promises information on both the scalar and spin polarisabilities of the neutron. We study in detail the sensitivities of 4 observables to the neutron polarisabilities. Including the Delta enhances those asymmetries from which neutron spin polarisabilities could be extracted.

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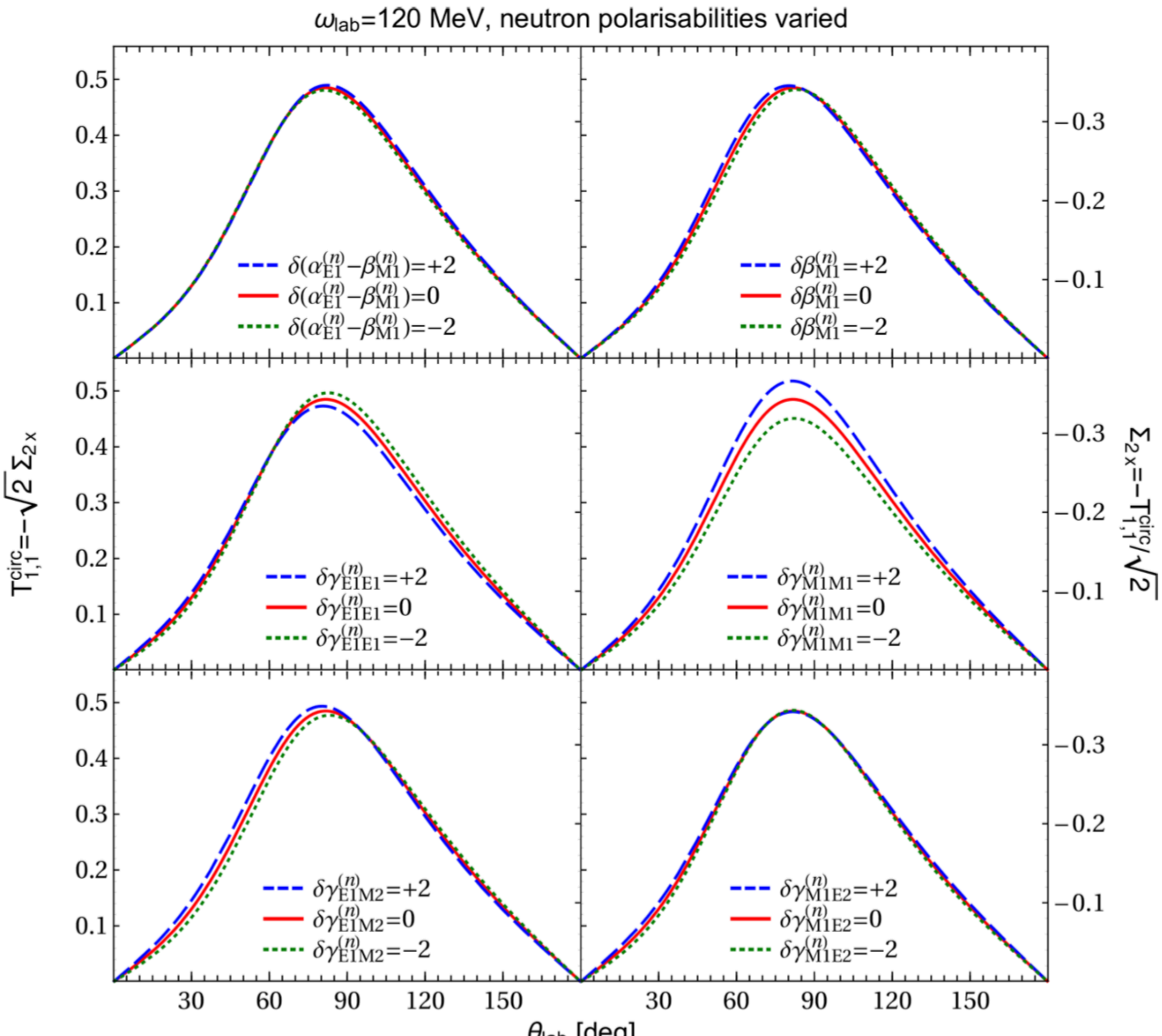

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