Gianluca Colo: The man whom we can trust

30 years collaborations on Nuclear Physics

Hiroyuki Sagawa
RIKEN/University of Aizu/ITP

Halon Bay, Vietnam
2003, Nov

Gianluca Colo CV

Higher education

- M.Sc. in Physics (it. Laurea in Fisica), 1989, Università degli Studi di Milano, 110/110 *cum laude* (thesis: "Neutron direct decay from the nuclear giant resonances", advisors: R.A. Broglia, P.F. Bortignon, A. Bracco)
- PhD in Physics, 1992, Università degli Studi di Milano (thesis: "Microscopic structure of the nuclear giant resonances", supervisor: R.A. Broglia)

Professional record

- Post-doctoral position, 10-12/1993, ECT* (European Center for Theoretical Nuclear Physics and Related Areas), Trento, Italy
- Post-doctoral position, 1994, IPN (Institut de Physique Nucléaire), Orsay, France. Contract within the CEE-supported network "Many-Body Theory of correlated fermion systems."
- Post-doctoral position, 01-06/1995, Università degli Studi di Milano
- Assistant Professor, 06/1995-09/2006, Università degli Studi di Milano
- Associate Professor, 10/2006-02/2017, Università degli Studi di Milano
- Full Professor, 03/2017-present, Università degli Studi di Milano

Gianluca Colo: The man whom we can trust

In Physics Research

Research Activities

more than 250 publications in refereed journals and conference and school proceedings and one book

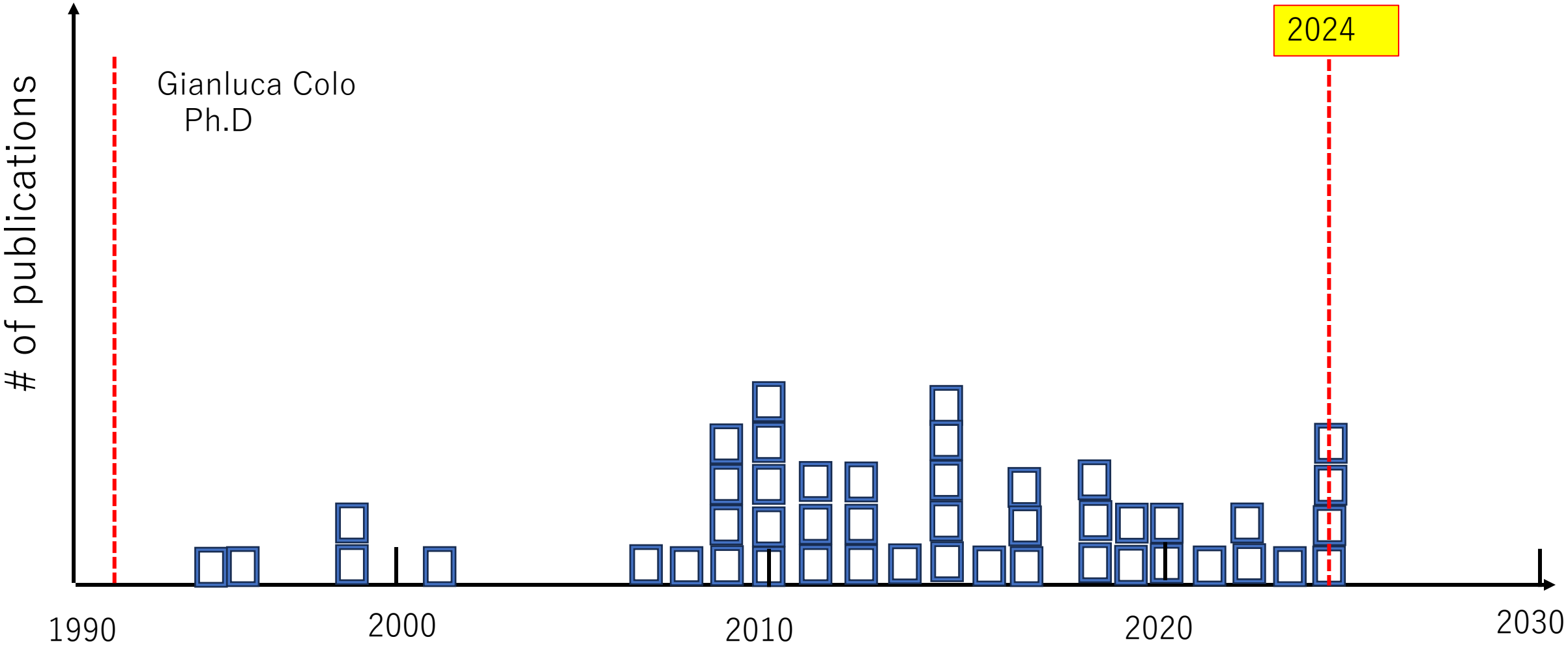
more than 7500 citations and a resulting h-index equal to 48 (source: Web of Science, August 2024)
11354citations, h-index 58 (Google scalar citation, Oct. 10, 2024) .

More than 130 invited talks and seminars in 2004-2022

Main interests

EDF: ab initio type, Skyrme-type
Giant Resonances: a self-consistent HF+RPA model
Particle-Vibration coupling (PVC)
Isospin symmetry invariance and breaking
Pairing properties of nuclei: self-consistent QRPA
Electro and molecular systems

About 50 joint papers in refereed journals
+20 proceedings papers+ ---
+ one book (2025)



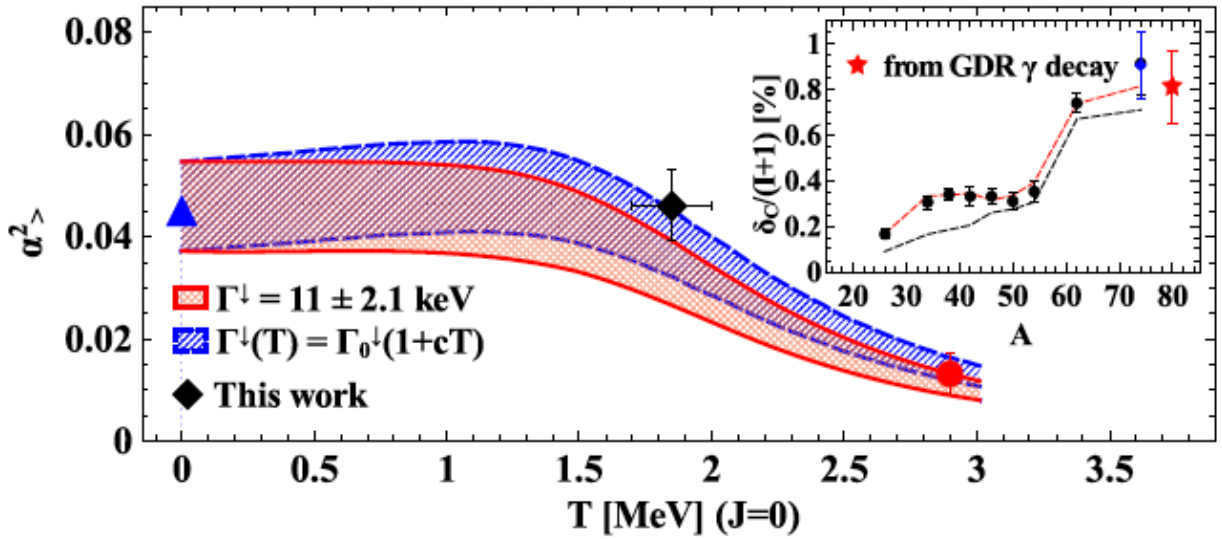
Title Author Journal	# of citations	year
Spin–orbit splitting and the tensor component of the Skyrme interaction G Colo, H Sagawa, S Fracasso, PF Bortignon Physics Letters B 646 (5-6), 227-231	300	2007
New Skyrme interaction with improved spin-isospin properties X Roca-Maza, G Colò, H Sagawa Physical Review C—Nuclear Physics 86 (3), 031306	154	2012
Effect of particle-vibration coupling on single-particle states: A consistent study within the Skyrm framework G Colo, H Sagawa, PF Bortignon Physical Review C82 (6), 064307	118	2010
Symmetry energy from the nuclear collective motion: constraints from dipole, quadrupole, monopole and spin-dipole resonances G Colo, U Garg, H Sagawa The European Physical Journal A 50, 1-12	117	2014
Effect of tensor correlations on Gamow–Teller states in 90Zr and 208Pb CL Bai, H Sagawa, HQ Zhang, XZ Zhang, G Colò, FR Xu Physics Letters B 675 (1), 28-31	114	2009

Title Author Journal	# of citations	year
Effect of the Tensor Force on the Charge Exchange Spin-Dipole Excitatio of CL Bai, HQ Zhang, H Sagawa, XZ Zhang, G Colò, FR Xu Physical review letters 105 (7), 072501	106	2010
Tensor interaction in mean-field and density functional theory approaches to nuclear structure H Sagawa, G Colò Progress in Particle and Nuclear Physics 76, 76-115	102	2014
Effects of the tensor force on the multipole response in finite nuclei LG Cao, G Colò, H Sagawa, PF Bortignon, L Sciacchitano Physical Review C80 (6), 064304	91	2009
Quenching of Gamow-Teller strength due to tensor correlations in and CL Bai, HQ Zhang, XZ Zhang, FR Xu, H Sagawa, G Colò	87	2009
Spin-isospin excitations as quantitative constraints for the tensor force CL Bai, HQ Zhang, H Sagawa, XZ Zhang, G Colo, FR Xu Physical Review C83 (5), 054316	78	2011

Isospin Mixing in ^{80}Zr: From Finite to Zero Temperature

S. Ceruti,[1,2] F. Camera,[1,2] A. Bracco,[1,2] R. Avigo,[1,2] G. Benzoni,[2] N. Blasi,[2] G. Bocchi,[1,2] S. Bottoni,[1,2] S. Brambilla,[2] F. C. L. Crespi,[1,2] A. Giaz,[2] S. Leoni,[1,2] A. Mentana,[1,2] B. Million,[2] A. I. Morales,[1,2] R. Nicolini,[1,2] L. Pellegri,[1,2] A. Pullia,[1,2] S. Riboldi,[1,2] O. Wieland,[2] B. Birkenbach,[3] D. Bazzacco,[4] M. Ciemala,[5] P. Désesquelles,[6] J. Eberth,[3] E. Farnea,[4] A. Görgen,[7,8] A. Gottardo,[9,10] H. Hess,[3] D. S. Judson,[11] A. Jungclaus,[12] M. Kmiecik,[5] W. Korten,[7] A. Maj,[5] R. Menegazzo,[4] D. Mengoni,[9,4] C. Michelagnoli,[9,4] V. Modamio,[10] D. Montanari,[9,4] S. Myalski,[5] D. Napoli,[10] B. Quintana,[13] P. Reiter,[3] F. Recchia,[9,4] D. Rosso,[10] E. Sahin,[10,8] M. D. Salsac,[7] P.-A. Söderström,[14,*] O. Stezowski,[15] Ch. Theisen,[7] C. Ur,[4]

PRL 115, 222502 (2015)



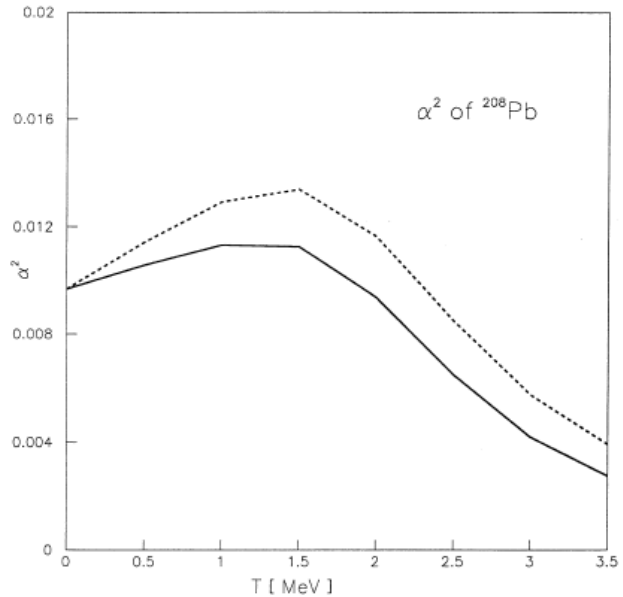


Fig. 1. The temperature dependence of the isospin mixing probability α^2 in ^{208}Bi. This probability is calculated by using Eq. (9), and assuming a linear temperature dependence for $\tilde{\Gamma}_M^\downarrow$ and $\tilde{\Gamma}_{\mathrm{IAS}}^\uparrow$ according to Eq. (11). The slope parameters c adopted in (11) are 0.025, and 0.05 for the solid and dashed curves, respectively. The value of $\tilde{\Gamma}_c$ is evaluated through Eq. (12).

$$\alpha^2_>(T) = \frac{1}{I_0+1}\frac{\Gamma^\downarrow_{\mathrm{IAS}}}{\Gamma_{\mathrm{CN}}(T)+\Gamma_{\mathrm{IVM}}(\mathrm{IAS})}, \qquad (2)$$

[11] H. Sagawa, P. F. Bortignon, and G. Colò, Phys. Lett. B **444**, 1 (1998); private communication.

Spin–orbit splitting and the tensor component of the Skyrme interaction

G. Colò [a,*], H. Sagawa [b], S. Fracasso [a], P.F. Bortignon [a]

[a] *Dipartimento di Fisica, Università degli Studi and INFN, Sezione di Milano, 20133 Milano, Italy*
[b] *Center for Mathematical Sciences, University of Aizu, Aizu-Wakamatsu, Fukushima 965-8560, Japan*

Received 22 December 2006; accepted 8 January 2007

Physics Letters B 646 (2007) 227–231

Skyrme parameter set plus the triplet-even and triplet-odd zero-range tensor terms, which read

$$
\begin{aligned}
v_T = \frac{T}{2}\Bigg\{&\Big[(\sigma_1\cdot\mathbf{k}')(\sigma_2\cdot\mathbf{k}') - \frac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}'^2\Big]\delta(\mathbf{r}_1-\mathbf{r}_2)\\
&+\delta(\mathbf{r}_1-\mathbf{r}_2)\Big[(\sigma_1\cdot\mathbf{k})(\sigma_2\cdot\mathbf{k}) - \frac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}^2\Big]\Bigg\}\\
&+U\Big\{(\sigma_1\cdot\mathbf{k}')\delta(\mathbf{r}_1-\mathbf{r}_2)(\sigma_1\cdot\mathbf{k}) - \frac{1}{3}(\sigma_1\cdot\sigma_2)\\
&\times\big[\mathbf{k}'\cdot\delta(\mathbf{r}_1-\mathbf{r}_2)k\big]\Big\}. \qquad (1)
\end{aligned}
$$

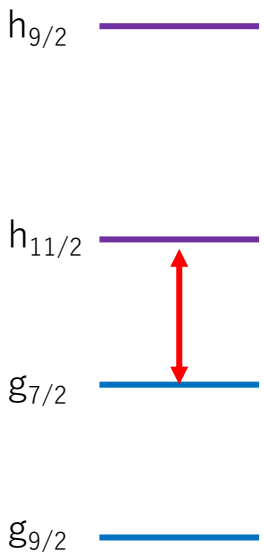
The spin–orbit potential is given by

$$
U^{(q)}_{\text{s.o.}} = \frac{W_0}{2r}\left(2\frac{d\rho_q}{dr} + \frac{d\rho_{q'}}{dr}\right) + \left(\alpha\frac{J_q}{r} + \beta\frac{J_{q'}}{r}\right), \qquad (4)
$$

$$
\alpha_C = \frac{1}{8}(t_1 - t_2) - \frac{1}{8}(t_1x_1 + t_2x_2),
$$

$$
\beta_C = -\frac{1}{8}(t_1x_1 + t_2x_2).
$$

$$
\alpha_T = \frac{5}{12}U, \qquad \beta_T = \frac{5}{24}(T+U).
$$



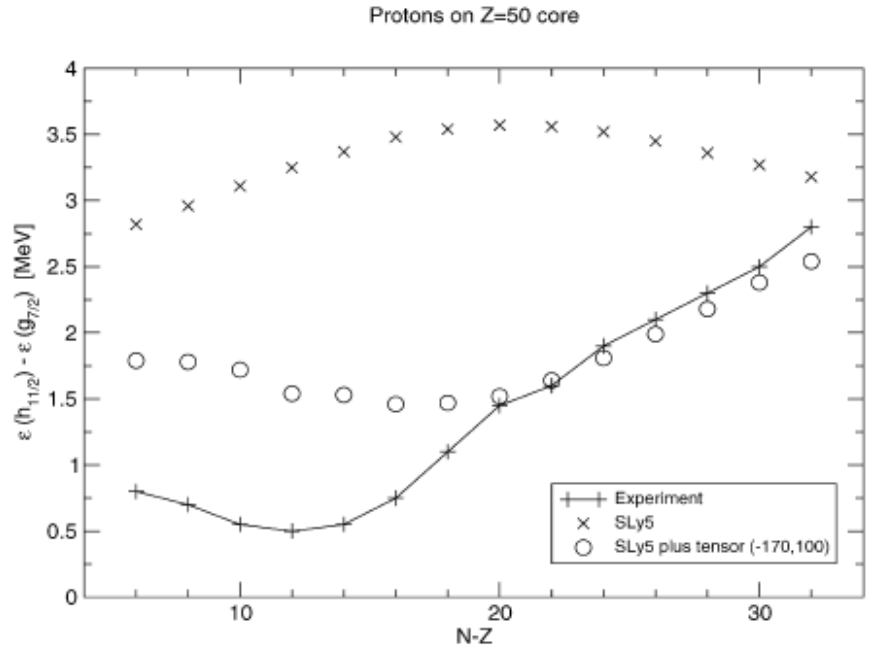


Fig. 1. Energy differences between the $1h_{11/2}$ and $1g_{7/2}$ single-proton states along the $Z = 50$ isotopes. The calculations are performed without (crosses) and with (circles) the tensor term in the spin–orbit potential (4), on top of SLy5 (which includes the central exchange, or J^2, terms). The experimental data are taken from Ref. [10]. See the text for details.

Z=50 isotopes

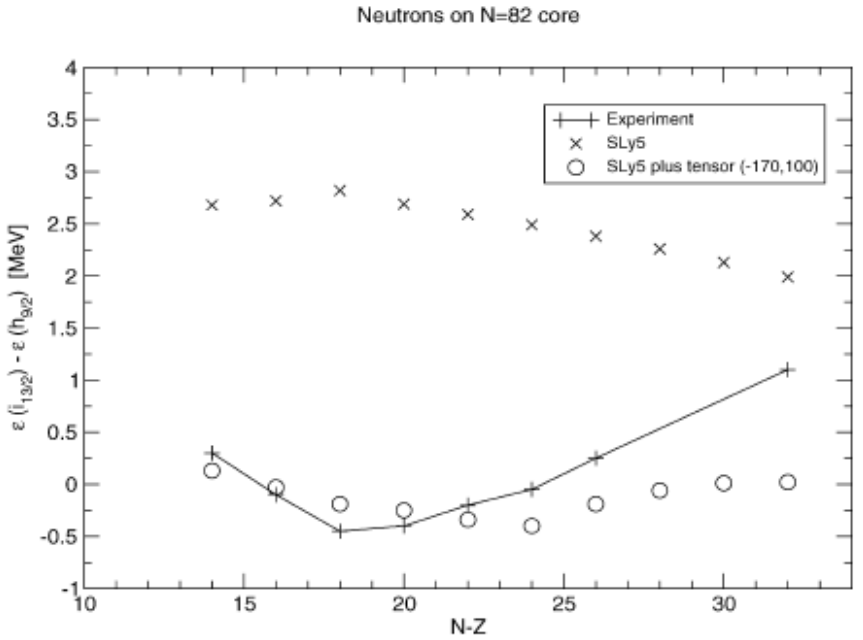
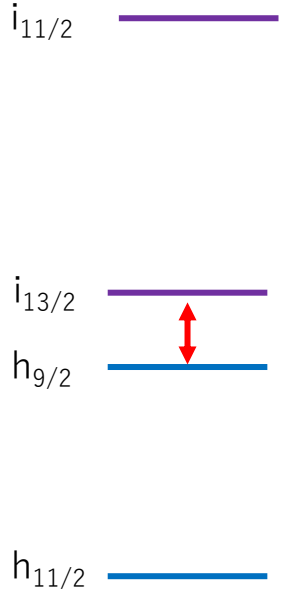


Fig. 2. Energy differences between the $1i_{13/2}$ and $1h_{9/2}$ single-neutron states along the $N = 82$ isotones. The calculations are performed without (crosses) and with (circles) the tensor term in the spin–orbit potential (4), on top of SLy5 (which includes the central exchange, or J^2, terms). The experimental data are taken from Ref. [10]. See the text for details.

N=82 isotones



+Many-p many-h effect=>PVC model

Tensor correlations

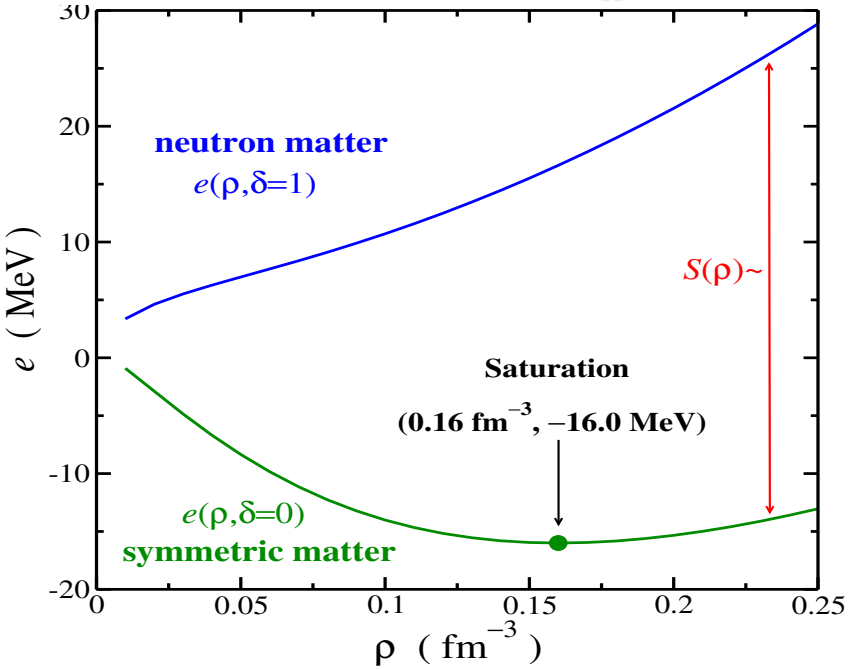
Application to spin-isospin excitations

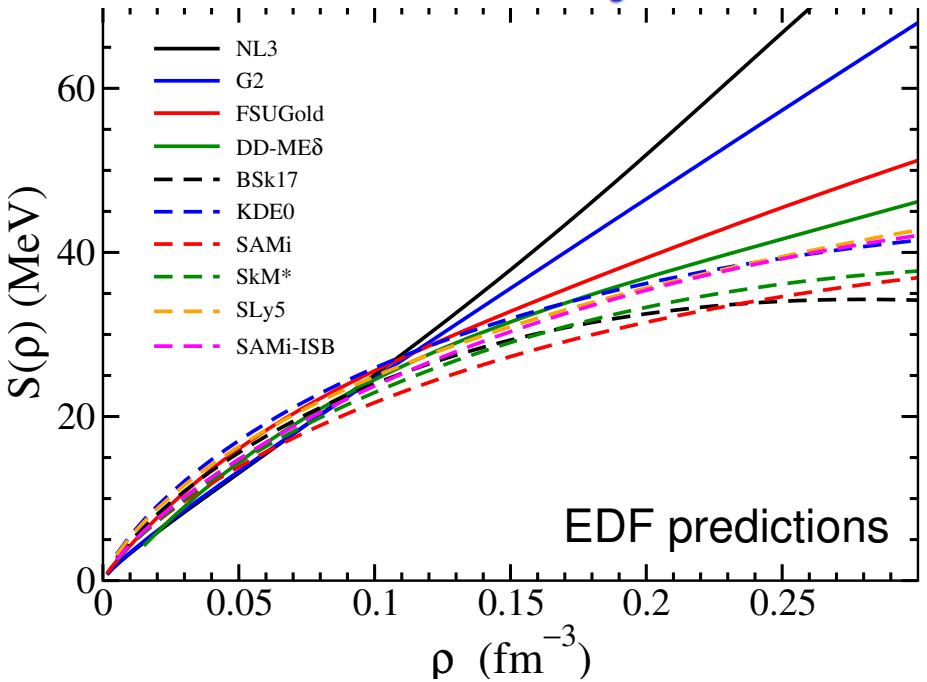
Gamow-Teller excitations

Magnetic Dipole excitations

Spin-dipole excitations

The Nuclear Equation of State: Infinite System





* The nuclear EoS can be written in good approximation as:

$$e(\rho,\beta) \approx e(\rho,\beta=0) + S(\rho)\beta^2 \text{ where } \beta \equiv \frac{\rho_n - \rho_p}{\rho_n + \rho_p}$$

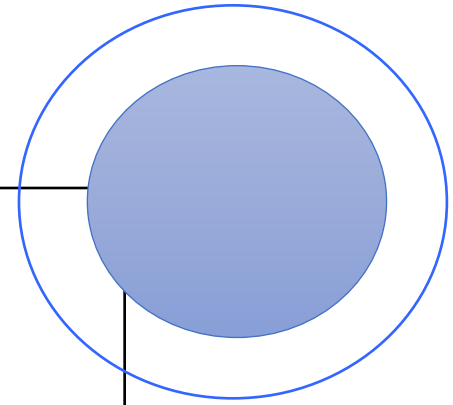
* SNM can be expanded around ρ_0 and define some useful parameters:

$$e(\rho,0) \approx e(\rho_0,0) + K\varepsilon^2 \text{ where } \varepsilon \equiv \frac{\rho_0 - \rho}{3\rho_0}$$

* Symmetry energy can be also expanded around ρ_0 and define some useful parameters:

$$S(\rho) \approx J - L\varepsilon + K_{sym}\varepsilon^2$$

Supernova Explosion



$$E_{ISGMR} = \sqrt{\frac{\hbar^2 K_A}{m < r^2 >_m}},$$

$$K_A = K_\infty + K_{surf} A^{-1/3} + K_\tau \delta^2 + K_{Coul} \frac{Z^2}{A^{4/3}},$$

Self consistent HF+RPA calculations

Self consistent RMF+RPA calculations

+PVC

(α,α') experimtent

The nuclear incompressibility from ISGMR

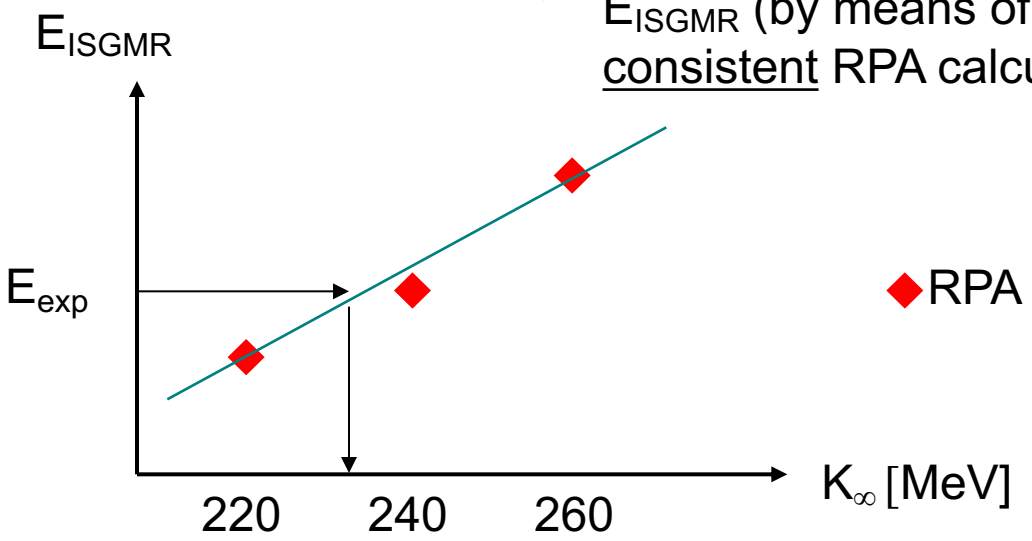
We can give credit to the idea that the link should be provided microscopically through the Energy Functional E[ρ].

J.P. Blaizot
1980

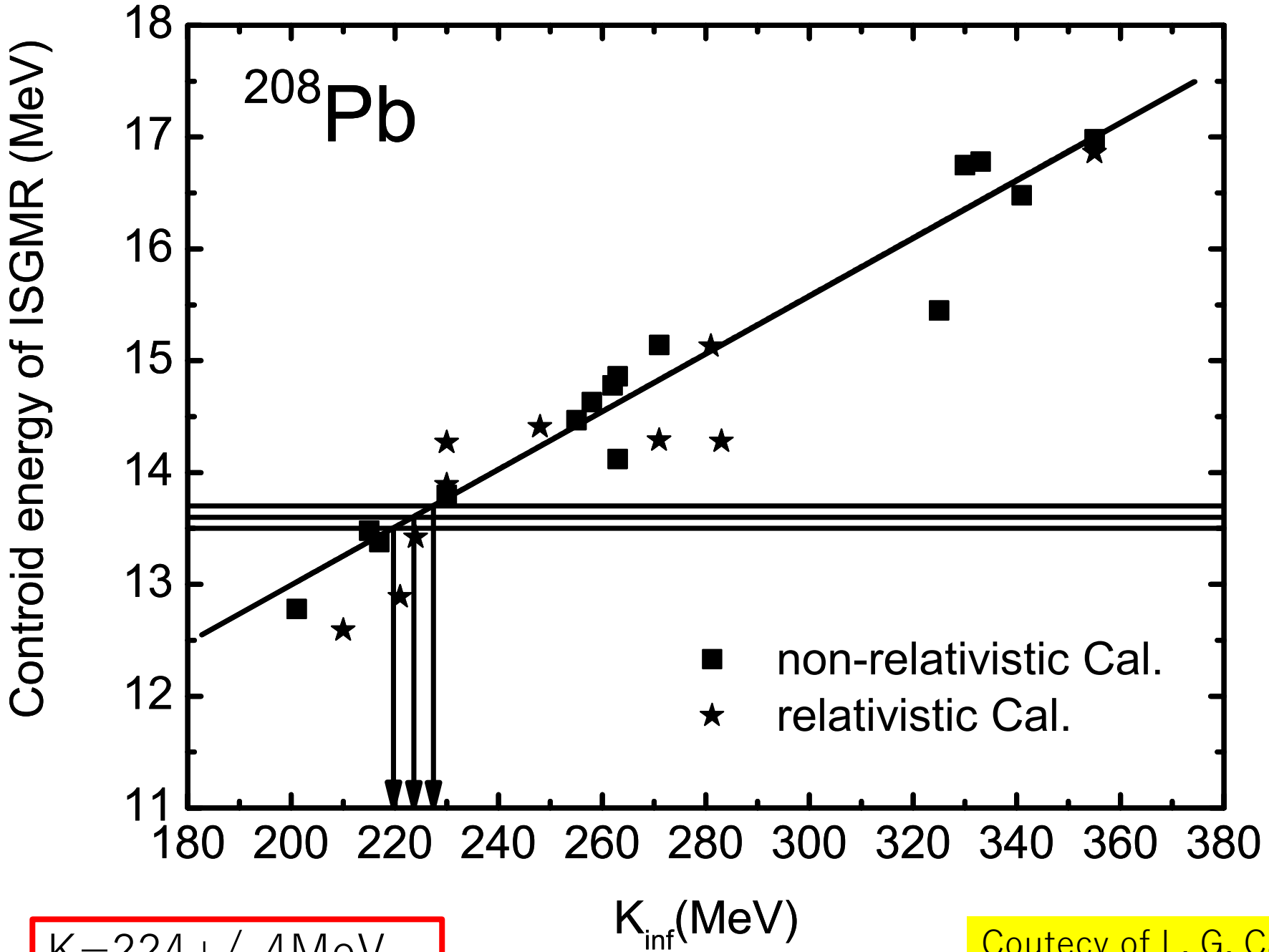
IT PROVIDES AT THE SAME TIME

- K_∞ in nuclear matter (analytic)
- E_{ISGMR} (by means of self-consistent RPA calculations)

Skyrme
Gogny
RMF

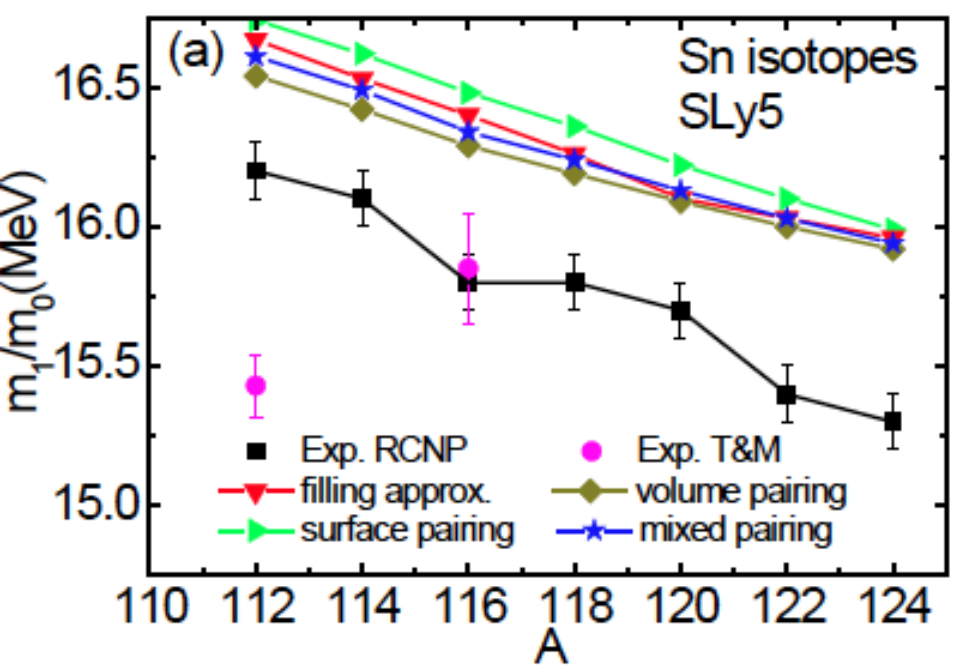


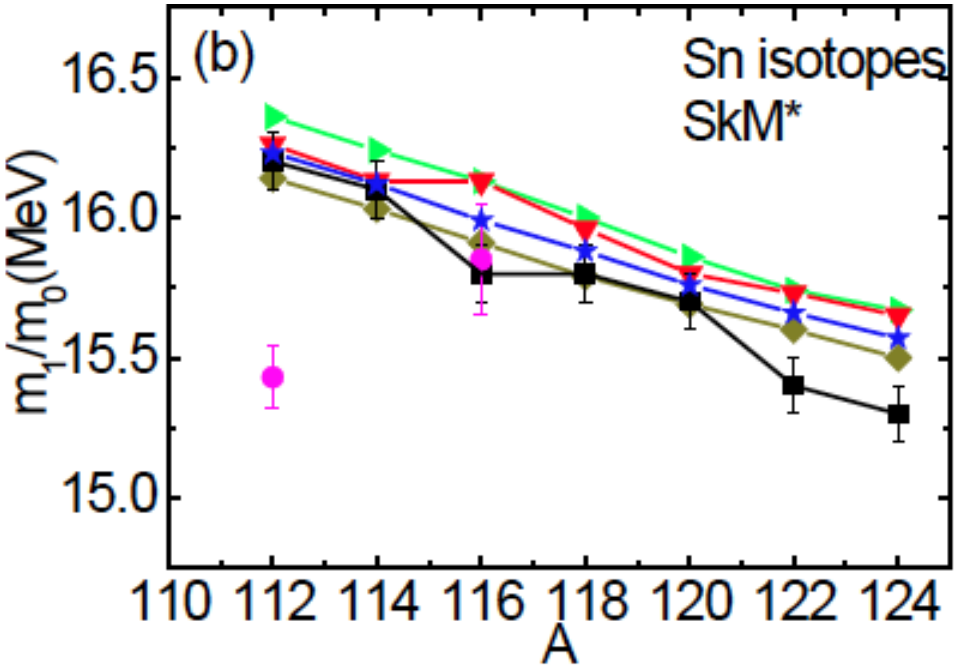
Extracted value of K_∞

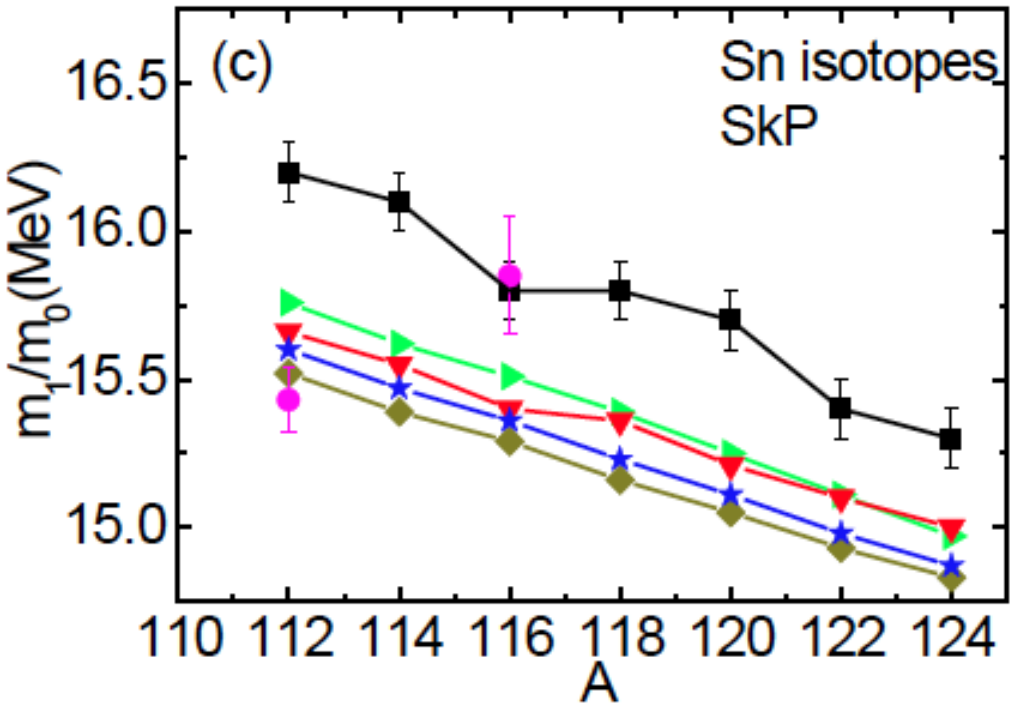


K=224+/-4MeV

Coutecy of L. G. Cao







SLy5 230*MeV*

SKM^* 217*MeV*

SKP 202*MeV*

Phys. Rev. C86, 054313, pp.1-10 (2012).
Li-Gang Cao, H. Sagawa, and G. Col o

Coulomb direct displacement energy

$$\left\langle \left[T_+, [H, T_-] \right] \right\rangle \Rightarrow$$

$$\Delta E_d \approx \Delta E_d^{C,direct} = \frac{1}{N-Z} \int [\rho_n(\vec{r}) - \rho_p(\vec{r})]\, U_C^{direct}(\vec{r})\, d\vec{r}$$

where $U_C^{direct}(\vec{r}) = \int \frac{e^2}{|\vec{r}_1 - \vec{r}|} \rho_{ch}(\vec{r}_1)\, d\vec{r}_1$

Assuming a uniform neutron and proton distributions of radius R_n and R_p respectively, and $\rho_{ch} \approx \rho_p$ one can find

$$\Delta E_d \approx \Delta E_d^{C,direct} \approx \frac{6}{5} \frac{Ze^2}{R_p} \left(1 - \frac{1}{2} \frac{N}{N-Z} \frac{R_n - R_p}{R_p} \right)$$

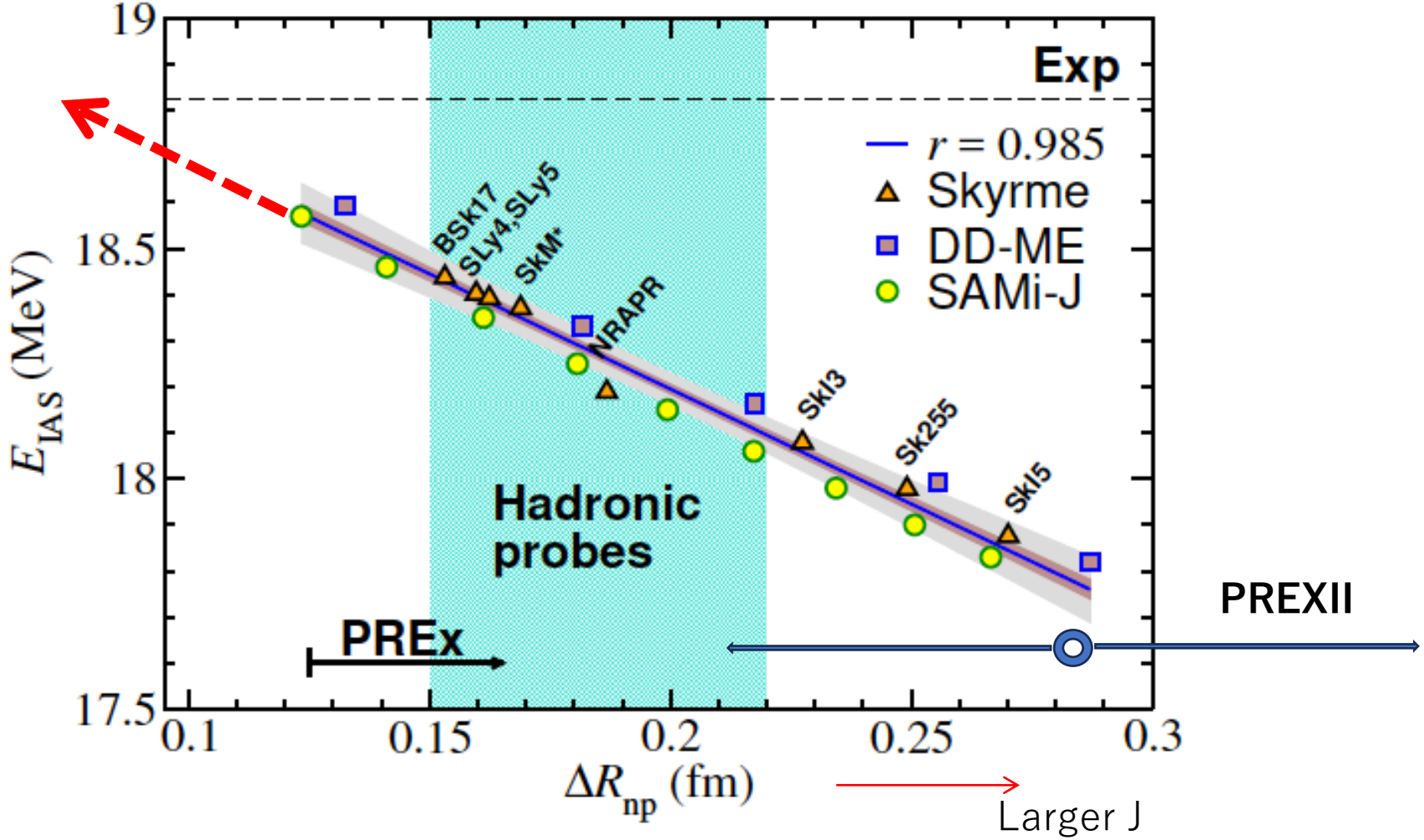
One may expect: **the larger the Δr_{np} the smallest E_{IAS}**

COULOMB ENERGIES AND THE EXCESS NEUTRON DISTRIBUTION FROM THE STUDY OF ISOBARIC ANALOG RESONANCES†

Naftali Auerbach, Jörg Hüfner, A. K. Kerman, and C. M. Shakin

	$\|\pi\rangle$ Parent State	Ca^{49}	Sr^{89}	Ba^{139}	Pb^{209}
E_R-E_A	Contin.-Comp. Mixing	-0.06	-0.10	-0.17	-0.48
	Dyn. p-n Mass Effect	0.04	0.04	0.04	0.04
	El.Magn. Spin Orbit	-0.07	-0.08	-0.01	-0.02
$\Delta E_d^{C.D.}$	Estimate Eq.(5)	-0.20	-0.16	-0.23	-0.25
	Phenomen. Force	-0.02	-0.16	—	—
ΔE_d^{Coul}	Direct Term	7.60	12.10	15.46	19.95
	Exchange Term	-0.31	-0.35	-0.35	-0.35
$\Delta E_d^{F.S.}$	Finite Proton Size	-0.10	-0.11	-0.11	-0.11
ΔE_d^{CORR}	Short Range Correlat.	~0.1	~0.1	~0.1	~0.1
ΔE_d^{T-IMP}	Collective Model	-0.01	-0.04	-0.06	-0.09
E_R-E_π	Theory	7.08±.20	11.40±.25	14.67±.25	18.79±.25
	Experiment	7.083±.015 (a)	11.40±.02 (a)	14.67±.02 (a)	18.790±.013 (b)
c_o [fm]	Charge Distribution	1.03	1.08	1.09	1.12
t [fm]	Charge Distribution	2.3	2.3	2.3	2.2
r_o [fm]	Neutron Potential	1.06±.08	1.10±.05	1.11±.05	1.12±.04
R_{rms} [fm]	Excess Neutrons	3.71±.18	4.36±.15	4.99±.15	5.63±.15
	Protons	3.42	4.10	4.75	5.42
	All Neutrons	3.51±.04	4.17±.05	4.83±.05	5.50±.05

E_{IAS} in Energy Density Functionals (No Corr.)



EDFs derived from Hartree-(Fock) + Random Phase approximations using relativistic (and non-relativistic) interactions where the nuclear part is isospin symmetric and U_{ch} is calculated from the ρ_p

IAS and CSB, CIB interactions

How can we reconcile this contradiction between IAS energy and neutron skin?

Xavi Roca-Maza, Gianluca Colo and HS

PHYSICAL REVIEW LETTERS 120, 202501 (2018)

Concept of Isospin proposed by J. Heisenberg, 1932 and E. P. Wigner, 1937

Isospin conservation $[H,T]=0$

$$[H,T]=[V_C+V_{CSB}+V_{CIB},T]\neq 0$$

Scattering Length

$$a^{pp}_{(S=0)} = -17.3\pm 0.4\text{fm},$$
$$a^{nn}_{(S=0)} = -18.7\pm 0.6\text{fm},$$
$$a^{pn}_{(S=0)} = -23.70\pm 0.03\text{fm}.$$

The difference between a_0^{pp} and a_0^{nn} is an evidence of CSB (charge symmetry breaking) nuclear force, while the difference between a_0^{pn} and the average $(a_0^{pp}+a_0^{nn})/2$ is due to CIB (charge invariance breaking) force.

Proton=(uud) $m_u c^2$~2.3MeV

Neutron=(udd) $m_d c^2$~4.8MeV

QCD dynamics of strong interaction

Explicit and Spontenous Chiral symmetry breaking

→ QCD sum rule **Phys. Rev. C109, L011302 (2024)**

SAMi-ISB finite nuclei properties

SAMI is refitted with the protocol

El.	N	B [MeV]	B^{exp} [MeV]	r_c [fm]	r_c^{exp} [fm]	ΔR_{np} [fm]
Ca	28	417.67	415.99	3.49	3.47	0.214
Zr	50	783.60	783.89	4.26	4.27	0.097
Sn	82	1102.75	1102.85	4.73	–	0.217
Pb	126	1635.78	1636.43	5.50	5.50	0.151

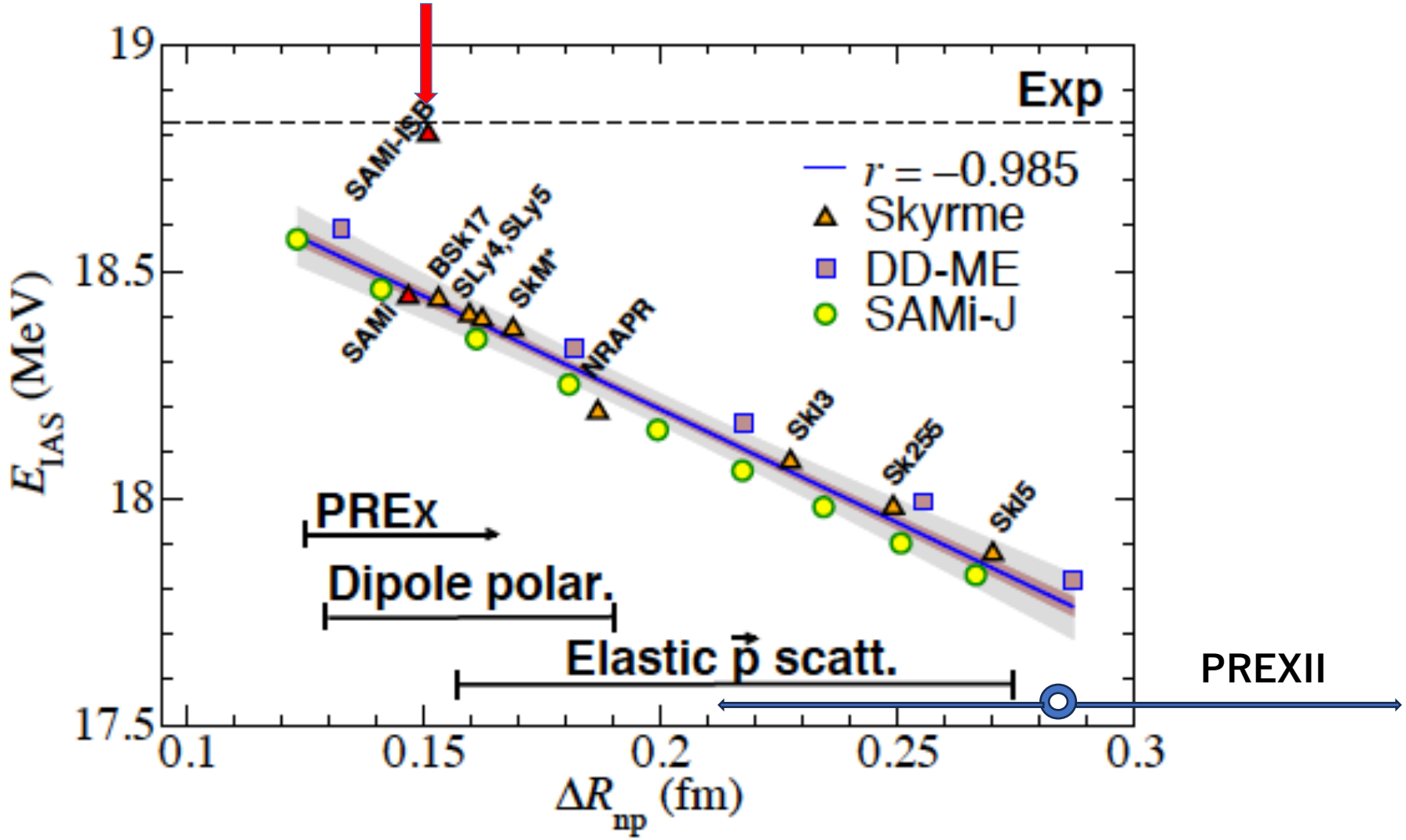
Corrections on E_{IAS} for ^{208}Pb one by one

	E_{IAS} [MeV]	Correction [keV]
No corrections[a]	18.31	
Exact Coulomb exchange	18.41	+100
n/p mass difference	18.44	+30
Electromagnetic spin-orbit	18.45	+10
Finite size effects	18.40	-50
Vacuum polarization (V_{ch})	18.53	+130
Isospin symmetry breaking	**18.80**	+270

[a] From Skyrme Hamiltonian where the nuclear part is isospin symmetric and V_{ch} is calculated from the ρ_p

$E_{IAS}^{exp} = 18.826 \pm 0.01$ MeV. *Nuclear Data Sheets 108, 1583 (2007).*

E_{IAS} with SAMi-ISB



Gianluca Colo: The man whom we can trust

In Education and Administration

- General Physics II, 1995-2001, Exercises and exams (B.Sc. students in Physics)
- Experimental Physics I, 1999-2001, 50 hours course (B.Sc. students in Physics)
- Physics Laboratory I, 2001-2006, 50 hours course (B.Sc. students in Physics)
- Nuclei under extreme conditions, 2004-2009, 40 hours course (M.Sc. students in Physics)
- General Physics, 2007-2010, 48 hours course (B.Sc. students in Computer Science)
- Nuclear Physics, 2010-present, 48 hours course (M.Sc. students in Physics)
- Electromagnetism, 2011-present, 80 hours course (B.Sc. students in Physics)

- supervisor of many B.Sc. and M.Sc. works and several PhD students

- Physics Department deputy Director from Oct. 1st, 2017 to Sep. 30th, 2020

Serving in National and International Committees

- Member of the Program Advisory Committee (B-PAC) for the Ring Cyclotron, RCNP, Osaka, Japan during 2008-2010
- Member of the Study Group for the special project INFN-SPES (Selective Production of Exotic Species, i.e. a new Radioactive Beam Facility to be complete at Legnaro, Italy) from May 2008 to December 2018
- Member of the Program Advisory Committee (PAC) of LNL (Laboratori Nazionali di Legnaro, Italy) from January 2012 to 2017
- Member and Chair of the NCN panel of evaluators (National Science Center, Poland)
- Member of the Editorial Board of International Journal of Modern Physics E

Referee and evaluator (Nature, PRC, +++++)

Research Project coordination (Asian Link, ++++)

Conference and workshop organization (20+ +++)

Gianluca Colo: The man whom we can trust

In Dairy Life

An excellent cook
An excellent driver and tour guide
Punctual：unusual as an Italian!
Good drinker

Cremona、
2014.11.22

May 2016
Como City

March 12th
2017 Mantova
Status of
Rigoletto

Asian Link
Beijing
2005.9.7

ISPUN2014
Vietnam
2014.11.5

2016
Happy time in Milano
=>
2024 + ------

Conclusions

Gianluca Colo: The man whom we can trust even more in future.

We are very happy to have you in Milano and our community.
We wants to have more exciting collaborations in all aspects of activities.

Gianluca Forever!

Thank you very much for your patience.