Coulomb excitation of neutron deficient radon and polonium isotopes

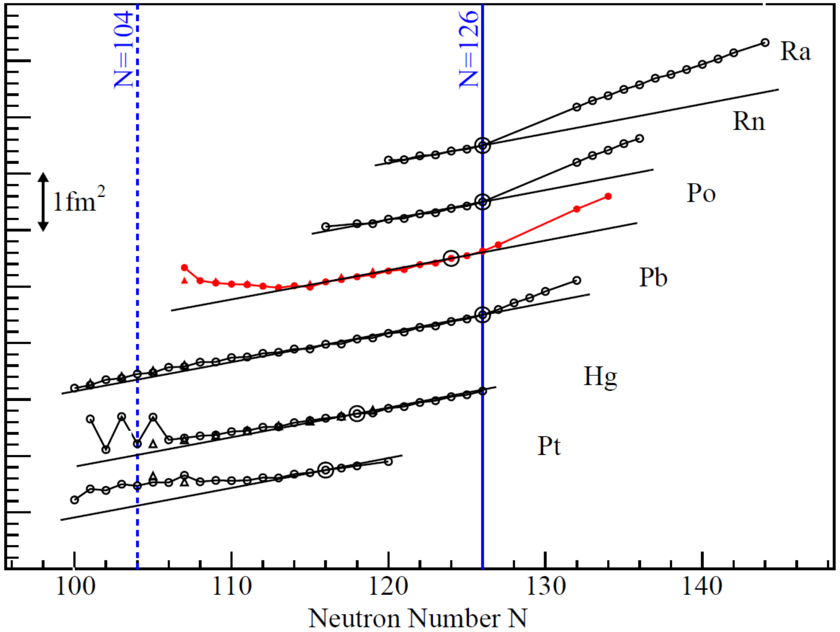
Liam Gaffney[1],
Nele Kesteloot[1,2]
On behalf of the IS465/IS479 collaboration

[1]KU Leuven, Instituut voor Kern- en Stralingsfysica, Leuven, B-3001, Belgium
[2]SCK CEN (Studiecentrum voor Kernenergie, Mol, B-2400, Belgium

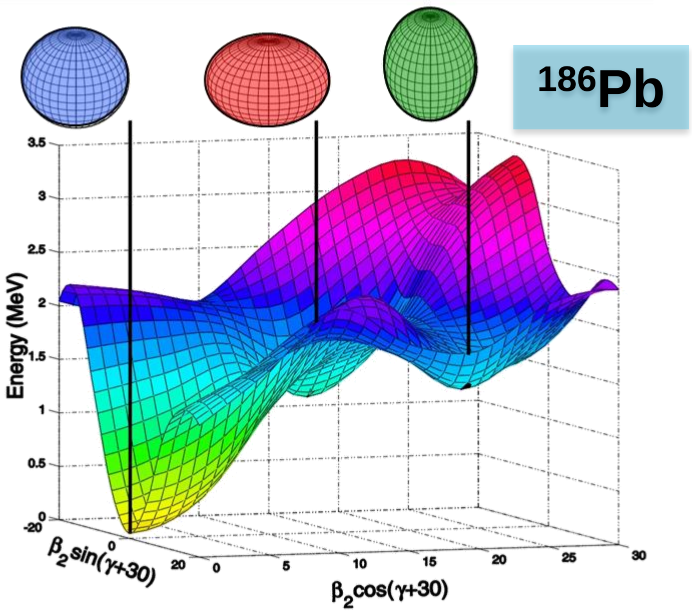
Shape coexistence

- Different types of deformation
- Interplay between two opposin
  - Stabilizing effect of closed she
  - Residual proton-neutron intera

Heyde and Wood, Review of Modern Physics (2011)



T.E. Cocolios et al, Phys. Rev. Lett. (2011)



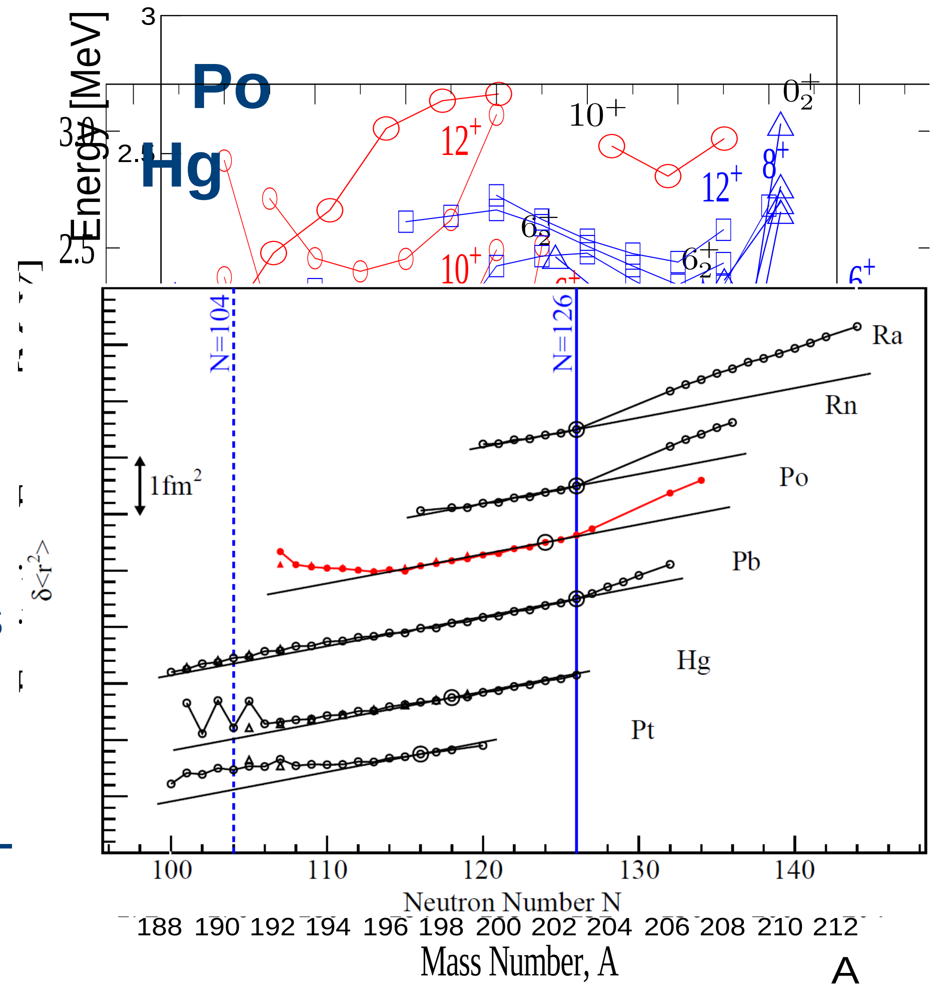
Andreyev et al Nature 405:430 (2000)

- Evidence across the light-lead region
- Lack of experimental information
  - Nature of deformation
  - Degree of mixing

KU LEUVEN

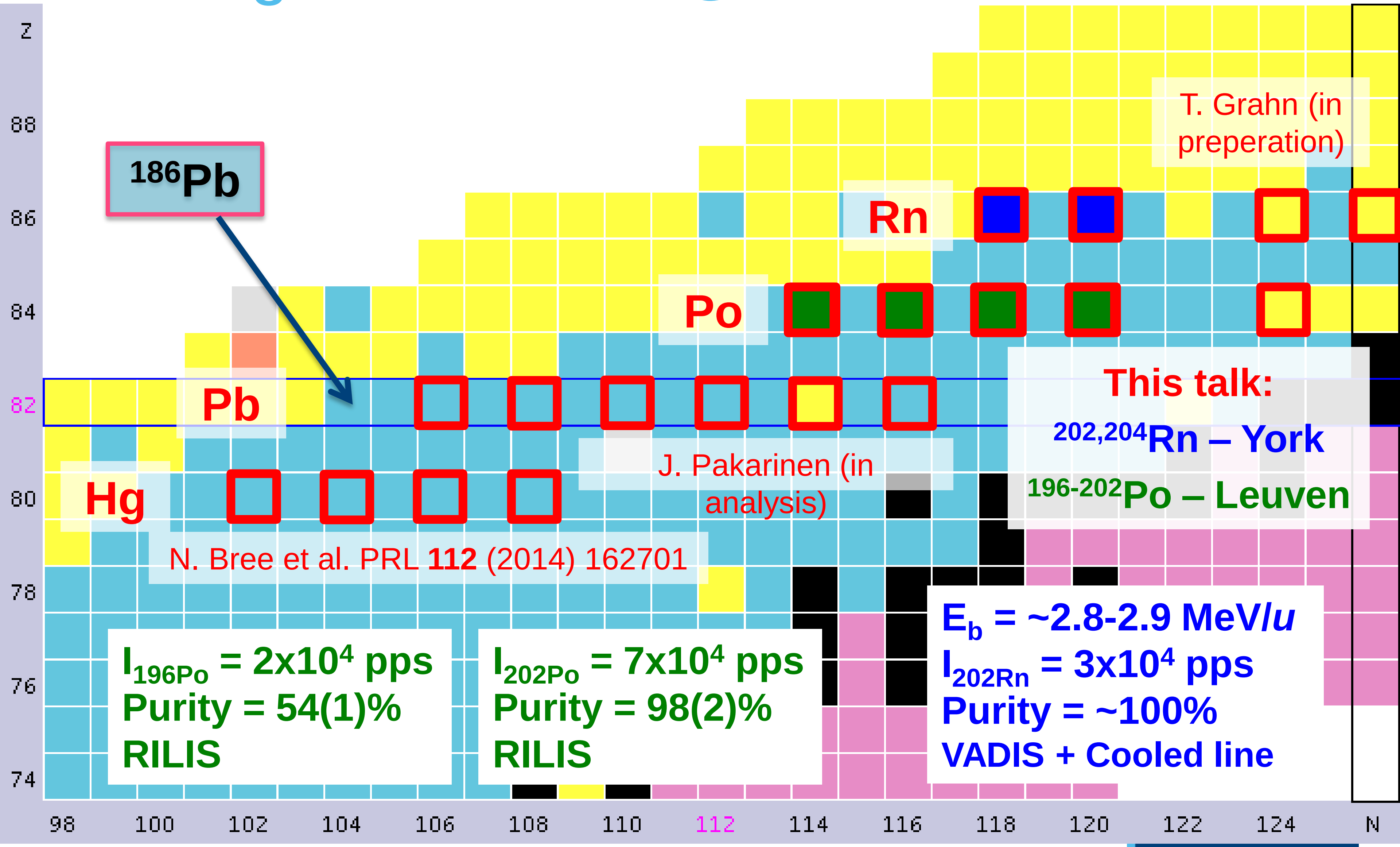
A complementary experimental picture: Above and below Z=82

- **Energy-level** systematics show intruder structure, usually parabolic.
- **Charge radii** reveal the onset of deformation.
- **B(E2)'s** detail couplings of states within structures.
- **Quadrupole moments** and inter-band **matrix elements** complete picture of shape.



KU LEUVEN

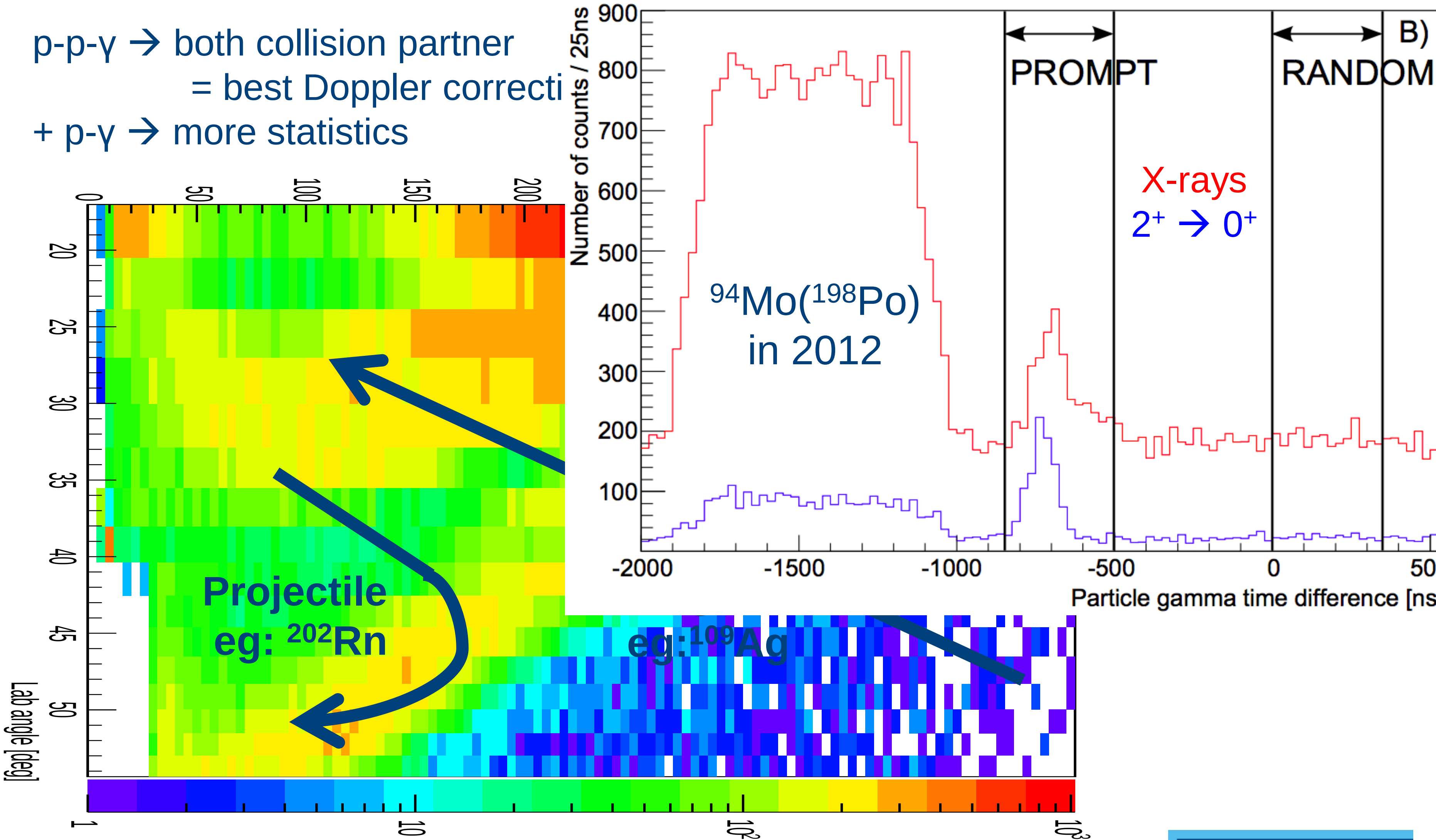
Pb region: Miniball @ REX-ISOLDE



KU LEUVEN

Coulomb excitation : Particle-γ

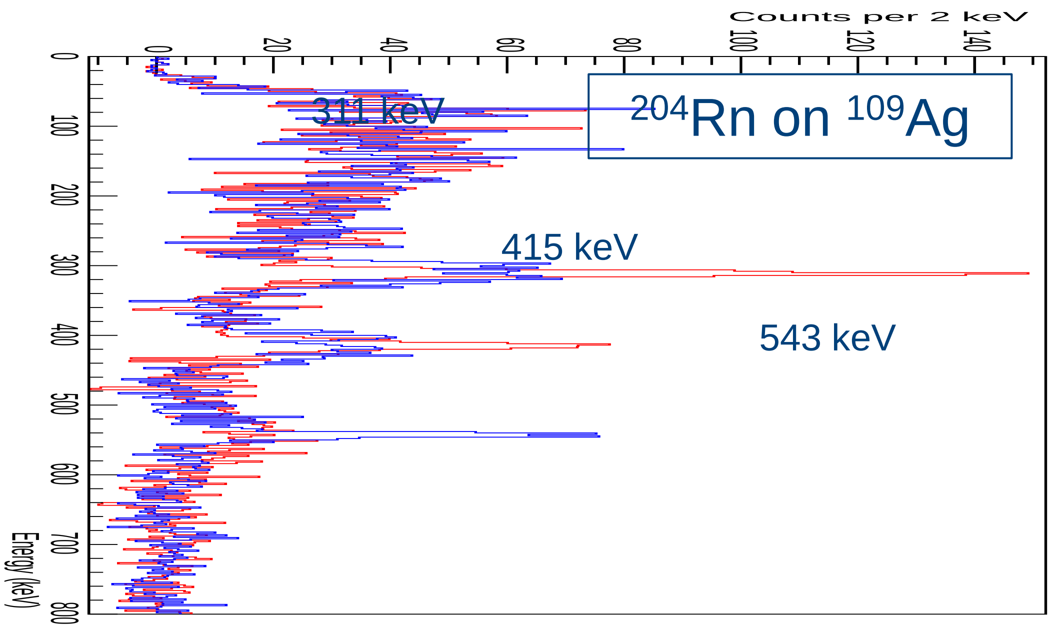
p-p-γ → both collision partner
= best Doppler correcti
+ p-γ → more statistics

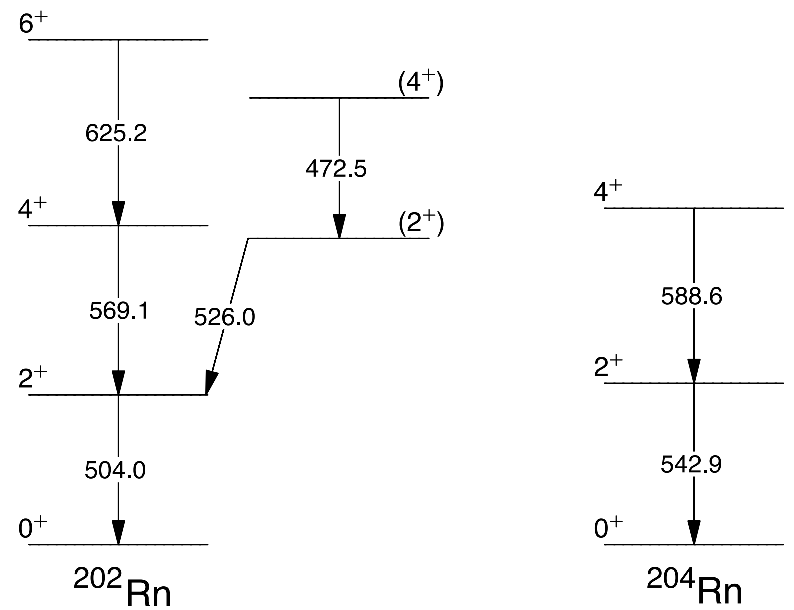


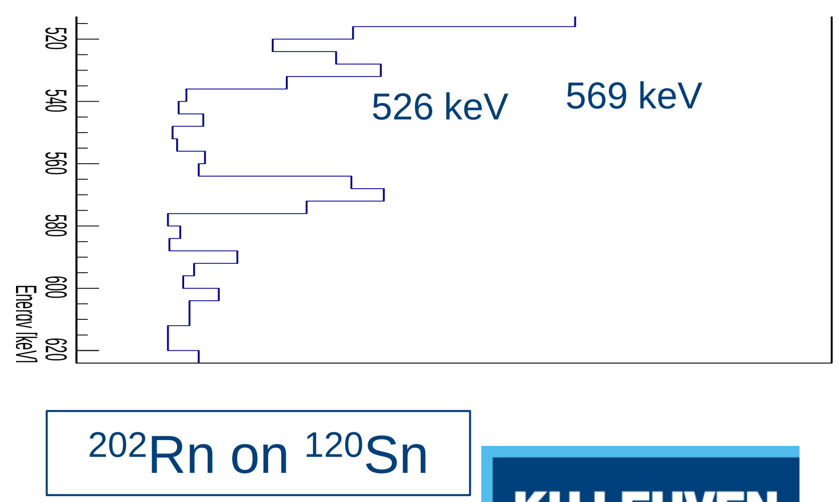
KU LEUVEN

Z = 86: ^{202,204}Rn: γ-ray spectra

- Population of 2^+_1 state only in ^{204}Rn
- 2^+_2 and 4^+_1 also observed in ^{202}Rn





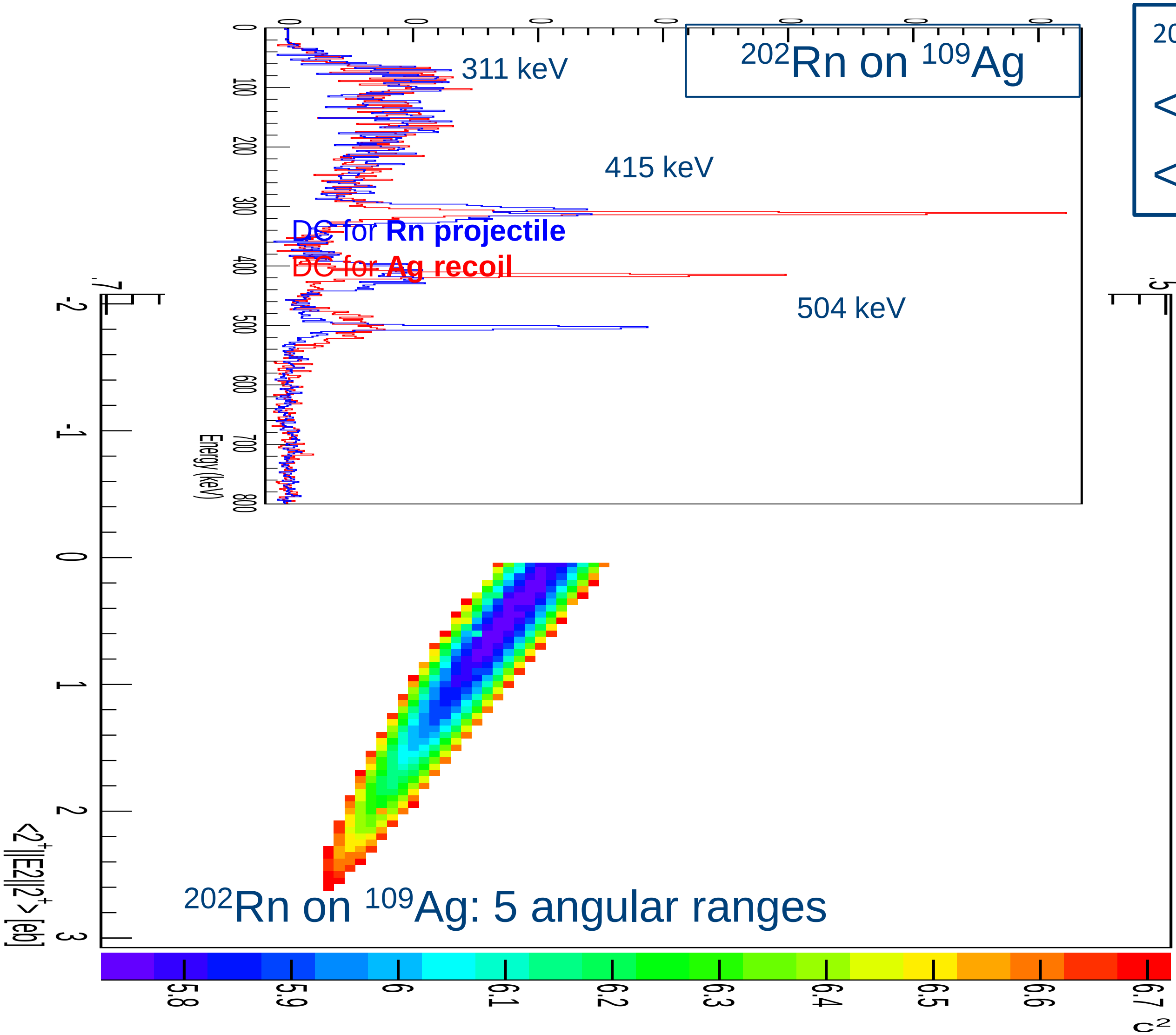


DC for **Rn projectile**

DC for **Ag recoil**

KU LEUVEN

Gosia2 results: Radon



^{202}Rn : χ^2_{min} = 5.73

$<0^+_1||E2||2^+_1>$ = 1.00(15) eb

$<2^+_1||E2||2^+_1>$ = $0.5(_{-1.7}^{+2.1})$ eb

^{120}Sn data : preliminary

$<2^+_1||E2||4^+_1>$ ~ 1.9 eb

$<2^+_1||E2||2^+_2>$ ~ 2.2 eb

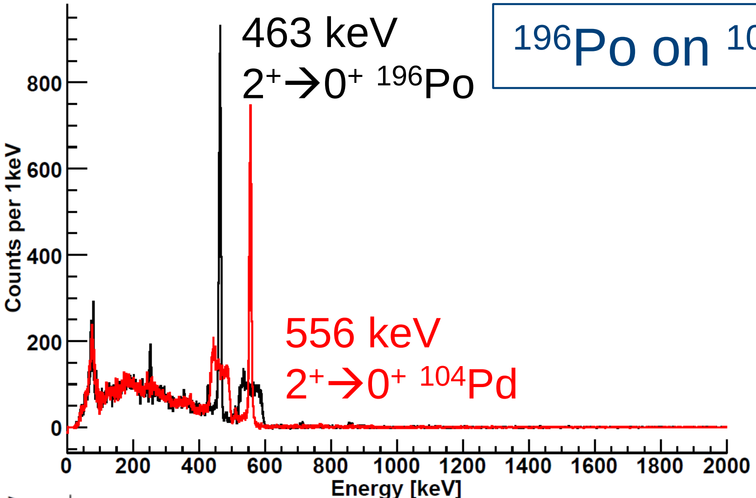
Vibrational states or intruder states?

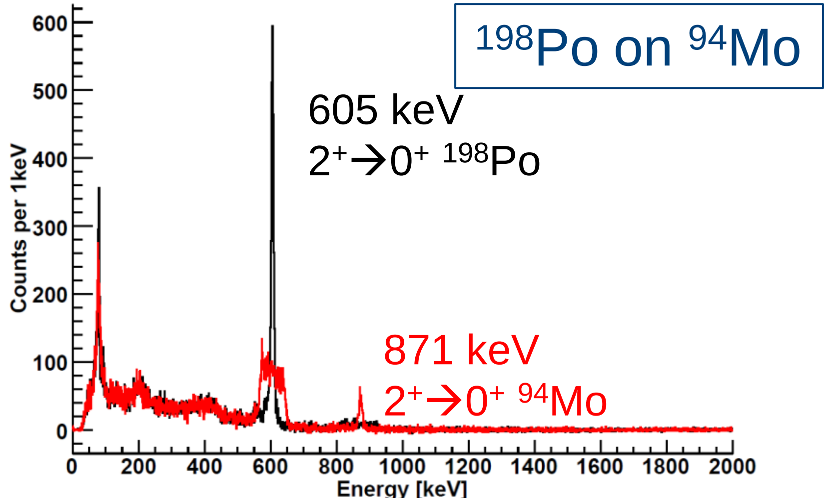
Must determine uncertainty

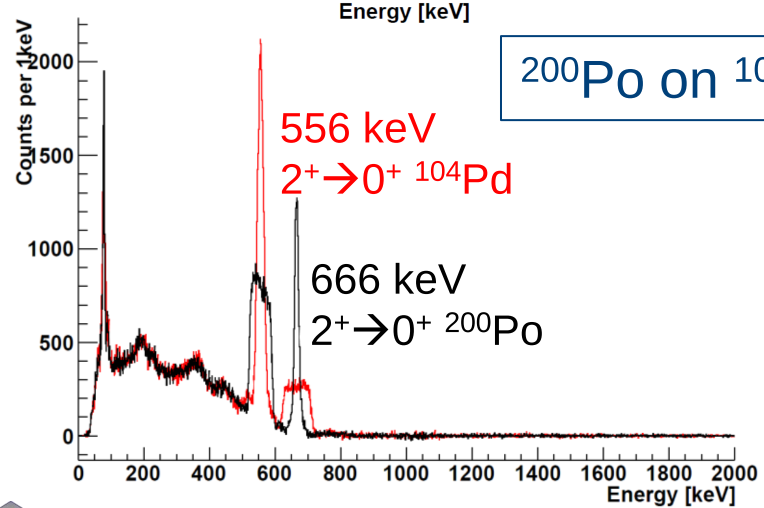
KU LEUVEN

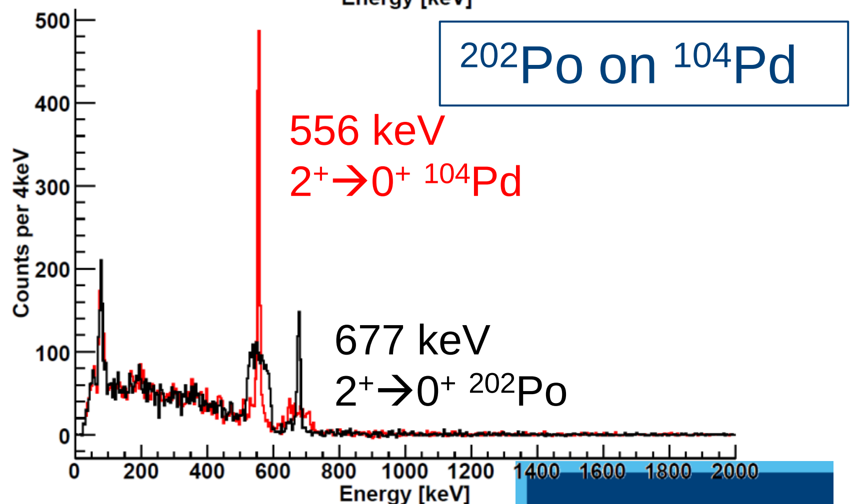
Z = 84: $^{196-202}$Po: γ-ray spectra

pγ + ppγ events, Doppler corrected for projectile/target





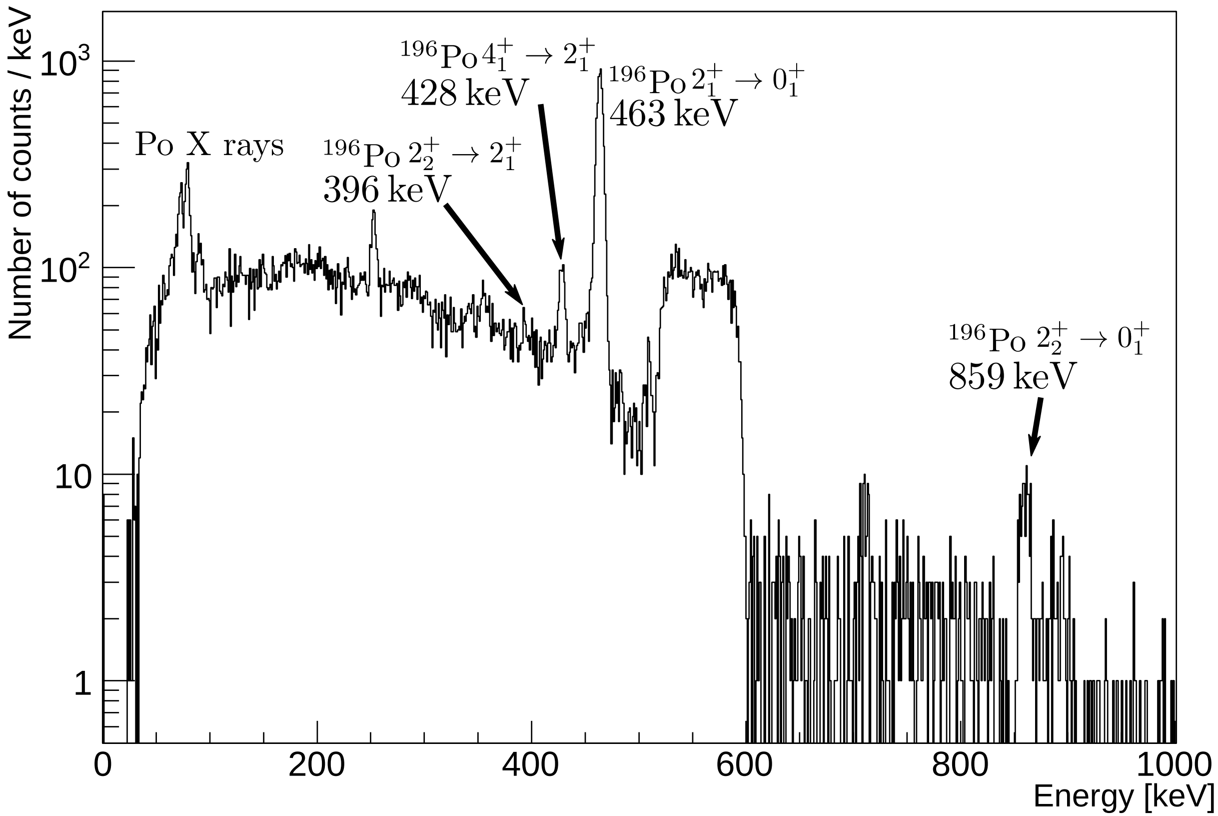


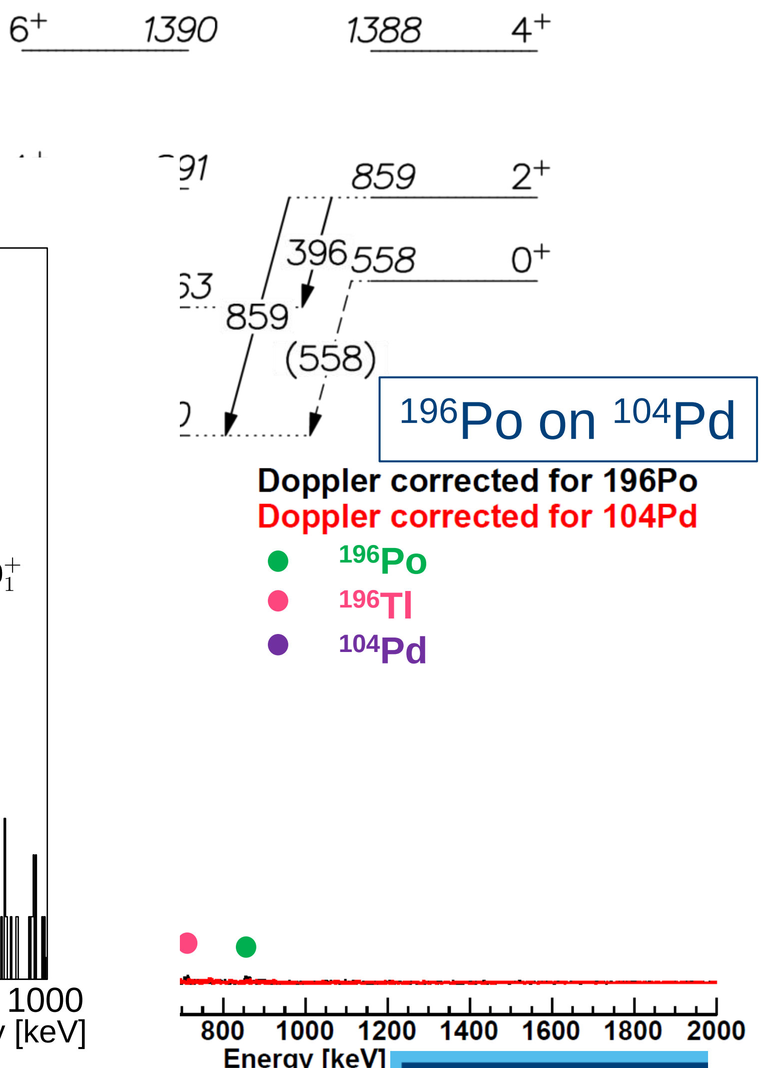


KU LEUVEN

Z = 84: $^{196\text{-}202}$Po: γ-ray spectra

- Population of 2^+_1 state in all isotopes
- Multi-step coulex observed in ^{196,198}Po

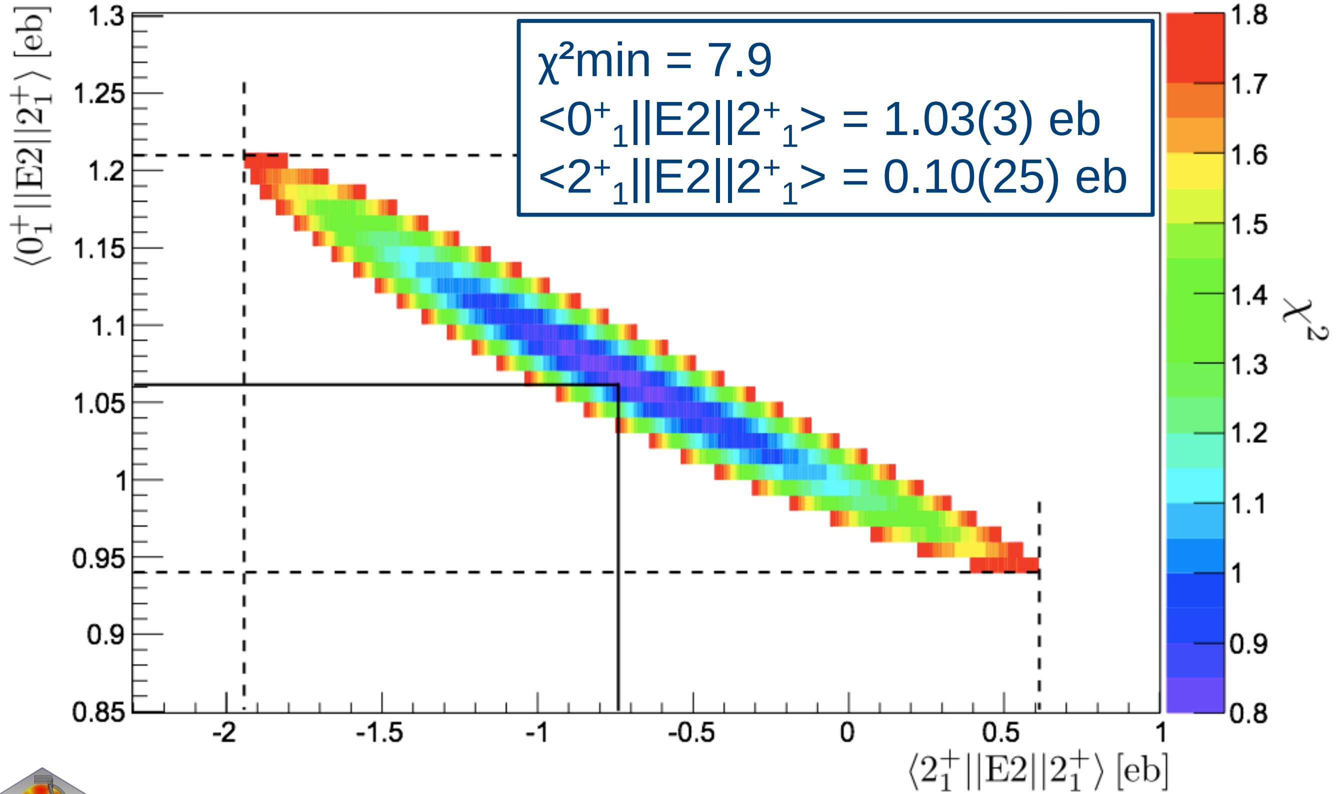




KU LEUVEN

Gosia results : Polonium

- If only 2^+_1 state populated
  - Extract $<0^+_1||E2||2^+_1>$ and $<2^+_1||E2||2^+_1>$
  - χ^2 surface to look for best solution
  - Example: ^{200}Po on ^{104}Pd



+ I(γ) + τ, etc…

→ **Gosia1**

If there are other states populated…

Iterate

Gosia1 →

Gosia2 →

Gosia1…

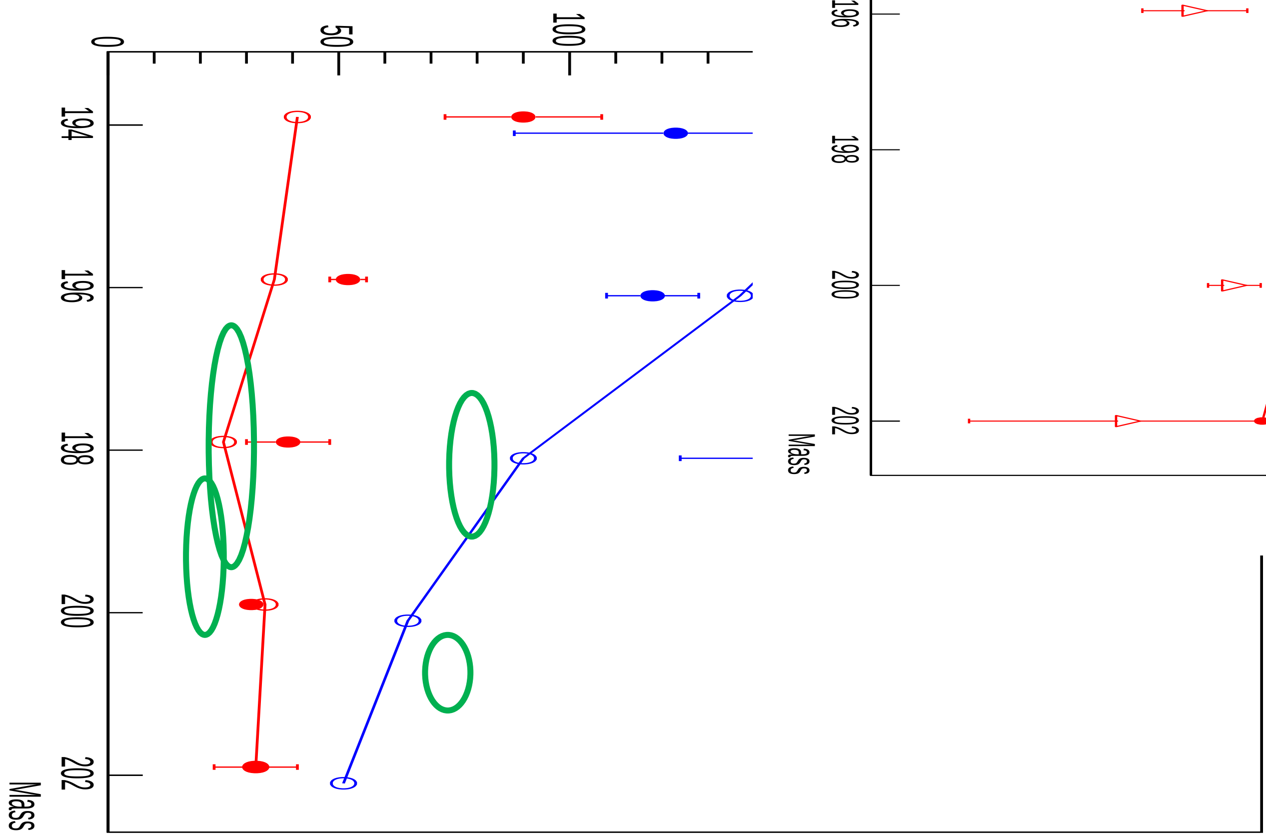
KU LEUVEN

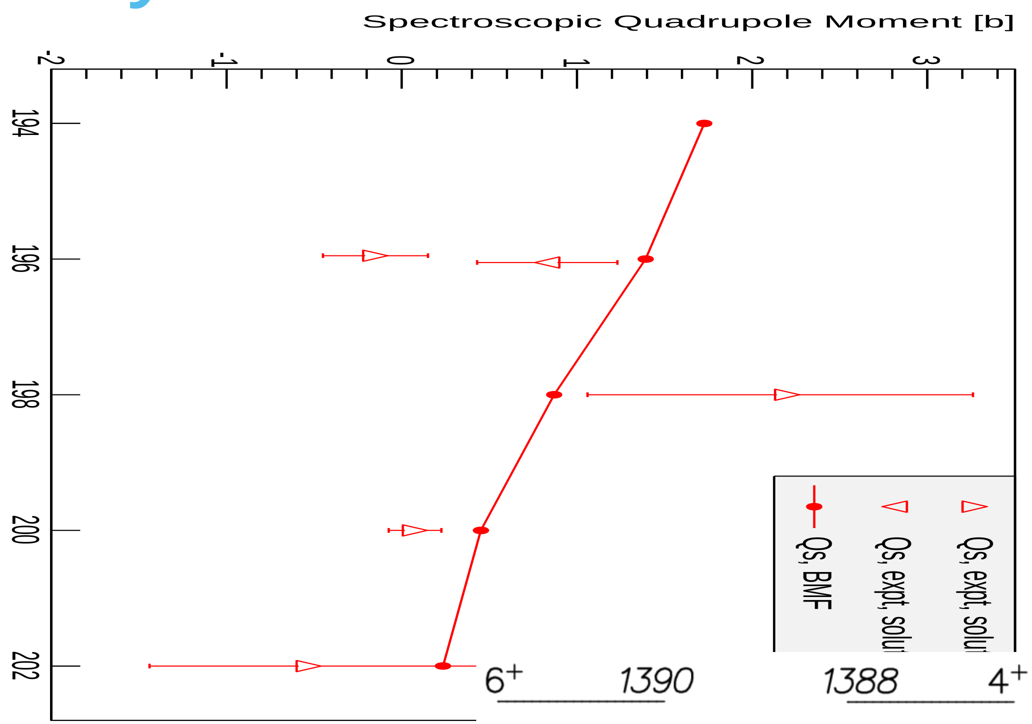
Comparison with Beyond Mean Field

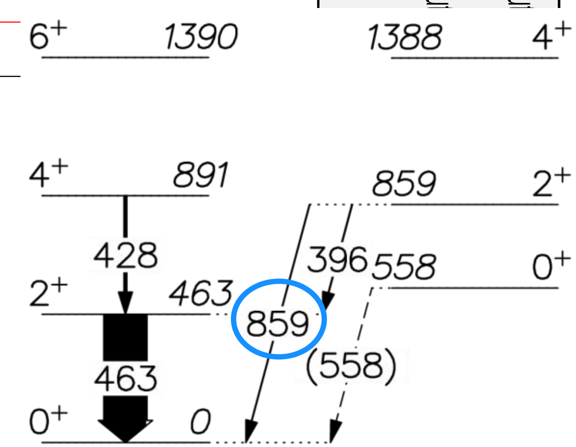
Lifetime experiments

^{194}Po: *T. Grahn et al* ***PRL*** *97, 062501 (2006)*

^{196}Po: *T. Grahn et al* ***PRC*** *80, 014323 (2009)*



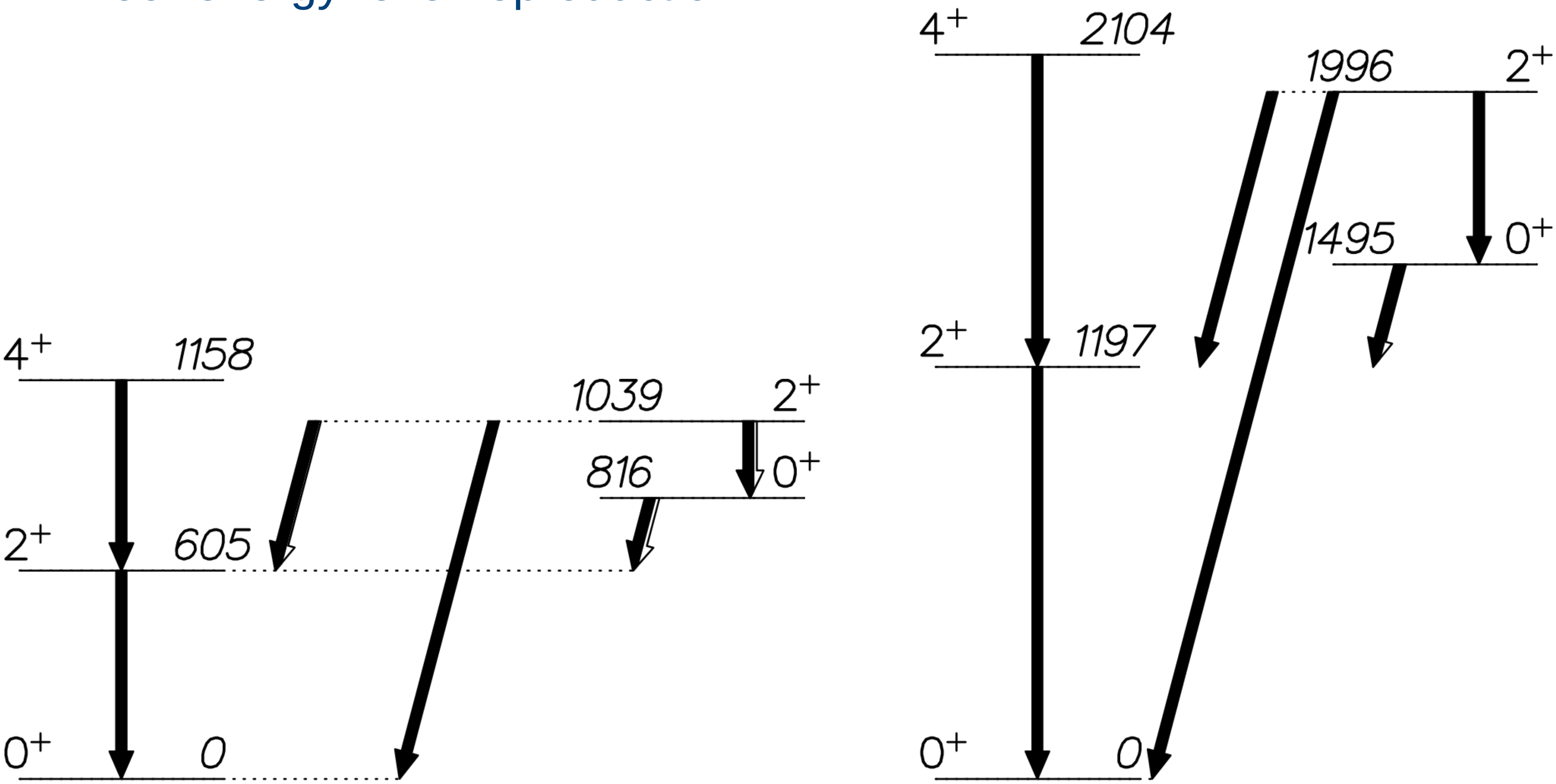




J.M. Yao, M. Bender, P.-H. Heenen PRC ***87****, 034322 (2013)*

Comparison with Beyond Mean Field: ^{198}Po

- Poor energy-level reproduction



Experiment

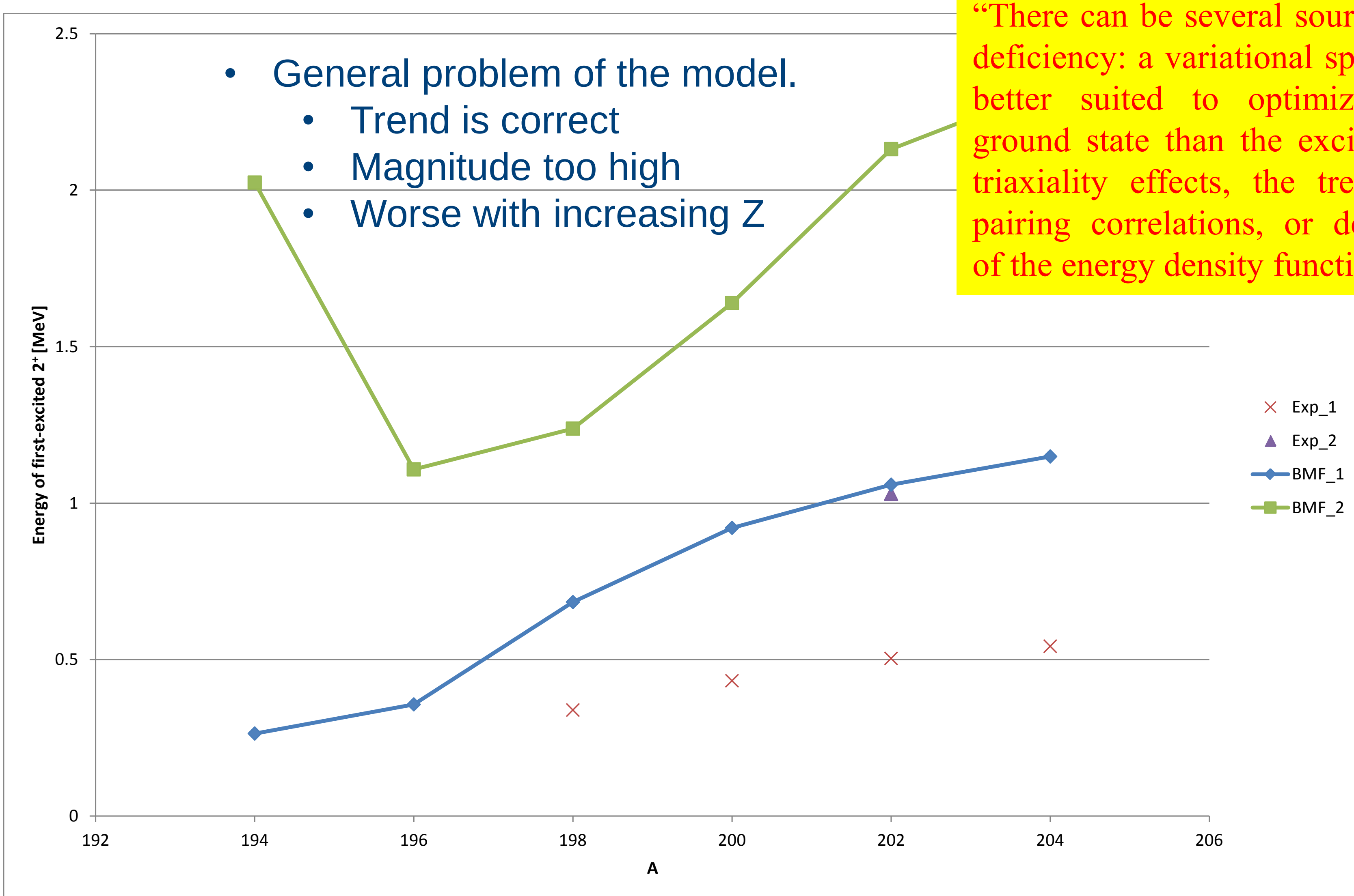
BMF

J.M. Yao, M. Bender, P.-H. Heenen PRC ***87****, 034322 (2013)*

Radon BMF: 2^+ Energies

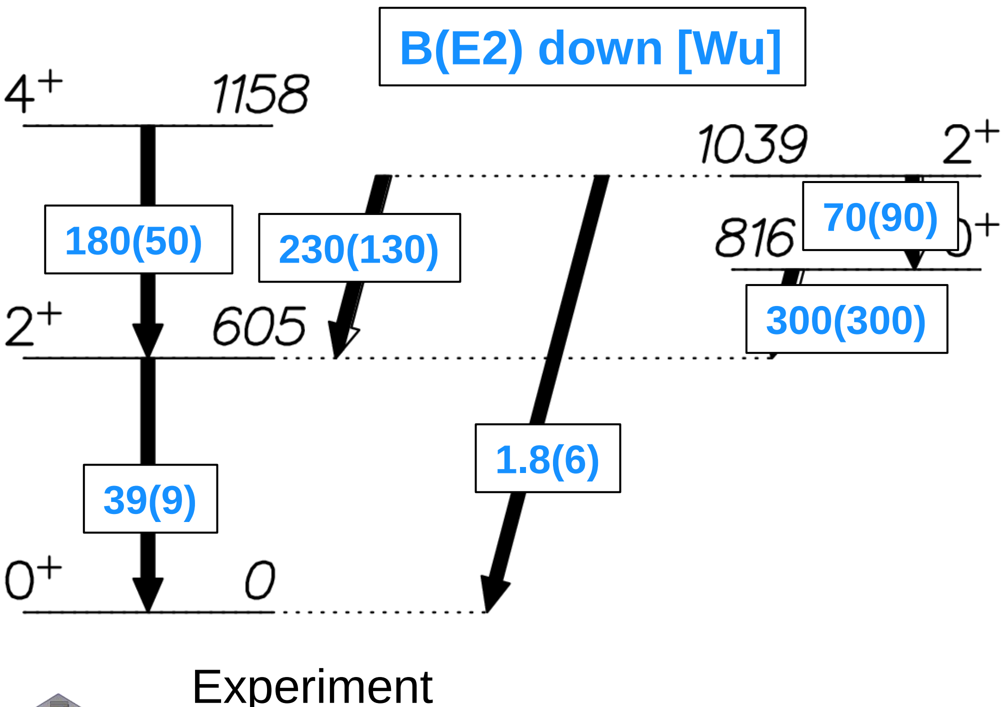
- General problem of the model.
  - Trend is correct
  - Magnitude too high
  - Worse with increasing Z

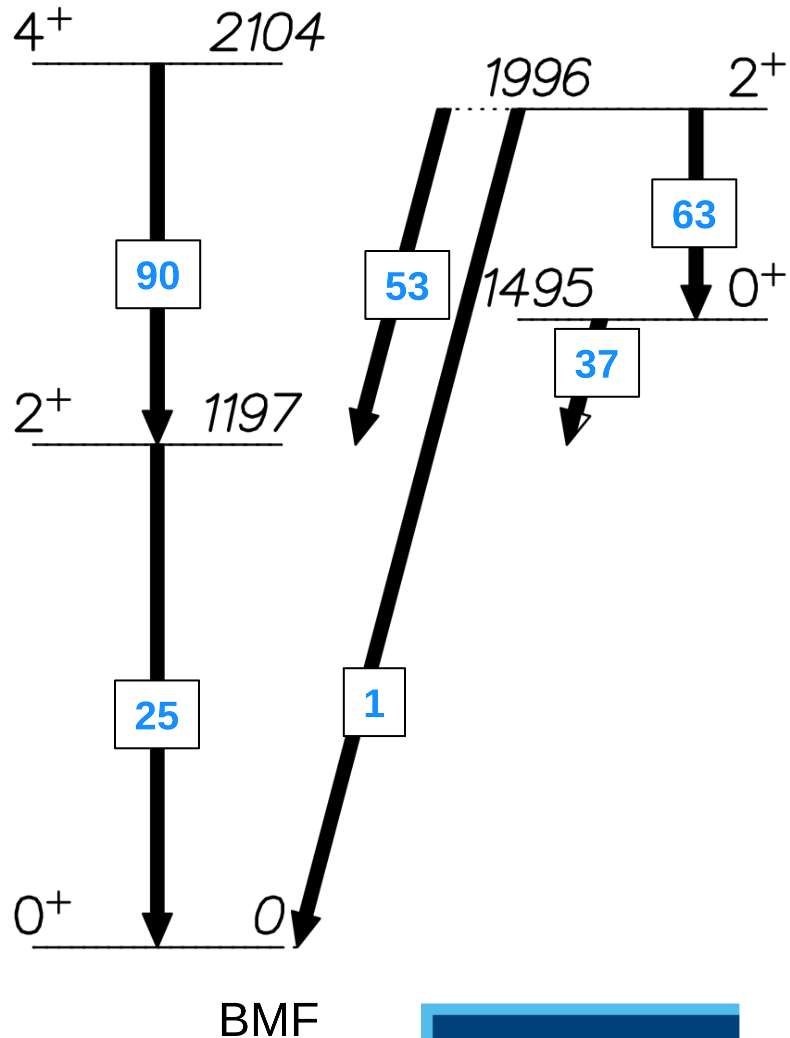
"There can be several sources to this deficiency: a variational space that is better suited to optimize the 0^+ ground state than the excited states, triaxiality effects, the treatment of pairing correlations, or deficiencies of the energy density functional."



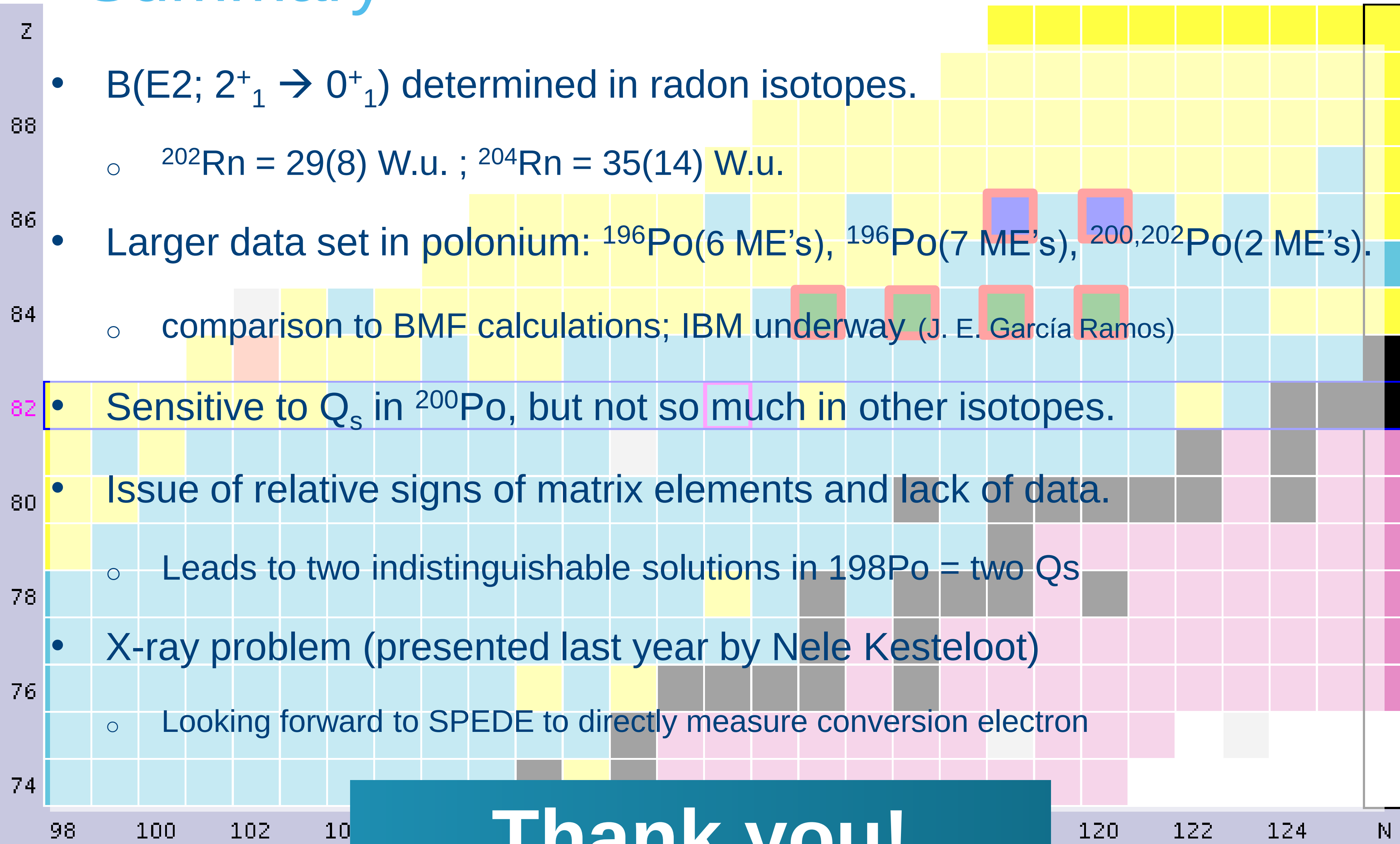
Comparison with Beyond Mean Field: ^{198}Po

- Poor energy-level reproduction
- Magnitude and relative B(E2) values are pretty good





Summary



- B(E2; $2^+_1 \rightarrow 0^+_1$) determined in radon isotopes.
  - ^{202}Rn = 29(8) W.u. ; ^{204}Rn = 35(14) W.u.
- Larger data set in polonium: ^{196}Po(6 ME's), ^{196}Po(7 ME's), ^{200,202}Po(2 ME's).
  - comparison to BMF calculations; IBM underway (J. E. García Ramos)
- Sensitive to Q_s in ^{200}Po, but not so much in other isotopes.
- Issue of relative signs of matrix elements and lack of data.
  - Leads to two indistinguishable solutions in 198Po = two Qs
- X-ray problem (presented last year by Nele Kesteloot)
  - Looking forward to SPEDE to directly measure conversion electron

Thank you!

Thank you for your attention!

KU LEUVEN

N. Bree
H. De Witte
J. Diriken
L.P. Gaffney
M. Huyse
N. Kesteloot
O. Ivanov
R. Orlandi
N. Patronis
I. Stefanescu
P. Van Duppen
K. Wrzosek-Lipska

HIL ŚLCJ

K. Hadynska-Klek
P.J. Napiorkowski
J. Srebrny

GANIL spiral2

B. Bastin
E. Clément
N. Lecesne

UNIVERSITY OF JYVÄSKYLÄ

T. Grahn
R. Julin
J. Konki
J. Pakarinen
P.J. Peura
P. Rahkila

ISOLDE

J. Cederkäll
V. Fedosseev
L.M. Fraile
B. Marsh
E. Piselli
E. Rapisarda
M. Seliverstov
T. Stora
D. Voulot
J. Van de Walle
F. Wenander

Universität zu Köln

A. Blazhev
B. Bruyneel
Ch. Fransen
K. Geibel
H. Hess
P. Reiter
B. Siebeck
N. Warr
A. Wiens

MANCHESTER 1824
The University of Manchester

T.E. Cocolios
A. Deacon
C. Fitzpatrick
S.J. Freeman
A.P. Robinson

TUM Technische Universität München

R. Gernhäuser
R. Krücken

The University of York

A. Andreyev
J. Butterworth
D.G. Jenkins
P. Marley

M. Guttormsen
A.C. Larsen
S. Siem
G.M. Tveten

UNIVERSITY OF LIVERPOOL

A. Petts
P.A. Butler
R.-D. Herzberg
R.D. Page

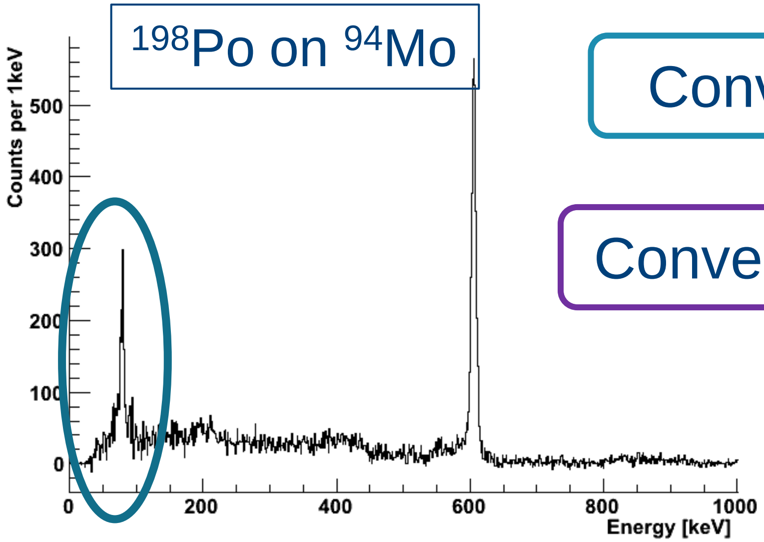
UNIVERSITY OF THE WEST of SCOTLAND UWS

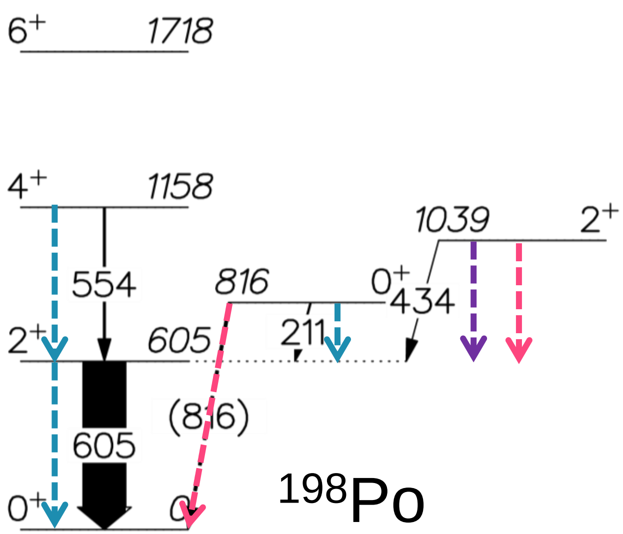
B. Hadinia
M. Scheck
J.F. Smith

P.-H. Heenen, Université Libre de Bruxelles
K. Heyde, Ghent University
J.L. Wood, Georgia Institute of Technology
T. Kröll, Technische Universität Darmstadt
M. Zielinska, CEA Saclay
M. Bender, Université Bordeaux
M. Carpenter, Argonne National Laboratory
A. Ekström, University of Lund
J.E. Garcia-Ramos, Universidad de Huelva

KU LEUVEN

Analysis of $^{196-202}$Po: Xrays





Xrays

Conversion of E2 γ's

Conversion of M1/E2 γ's

E0 transitions

- $0^+_2 \rightarrow 0^+_1$
- $2^+_2 \rightarrow 2^+_1$

Atomic production of K vacancy in ion-atom collision

KU LEUVEN

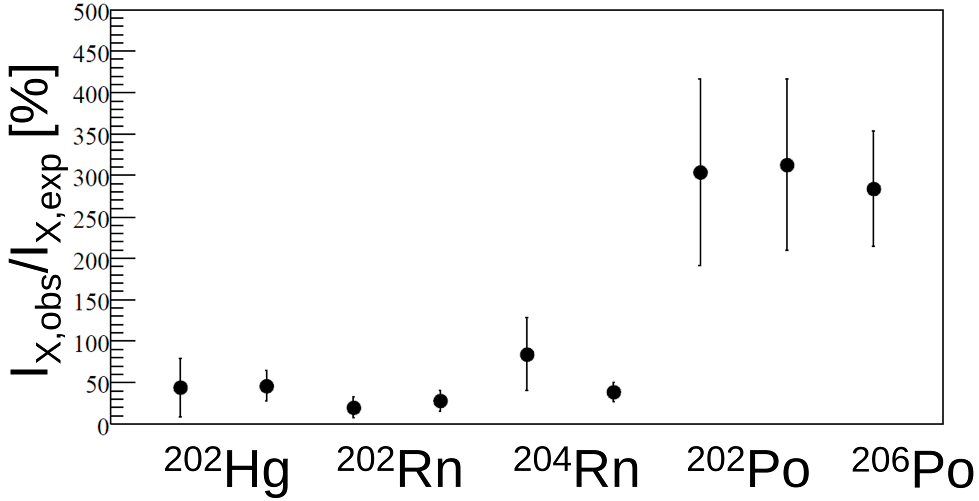
Atomic production of Xrays

- K vacancy creation in collision of beam and target

$$\sigma = Z_t^2 \frac{1}{\left(I_K^{0.95}\right)^2} \exp\left[\sum_{i=0}^{5} b_i \left(\ln\left(\frac{E_p}{\left(I_K^{0.95}\right)^2}\right)\right)\right]$$

J.D. Garcia et al, RMP 45 No 2 (1973) 111

- Scale experiment to theory
  - ^{188,202}Hg, ^{202,204}Rn, ^{202,206}Po
    - Take conversion into account
    - No E0 expected ($0^+_1 \rightarrow 0^+_2$ or $2^+_2 \rightarrow 2^+_1$)

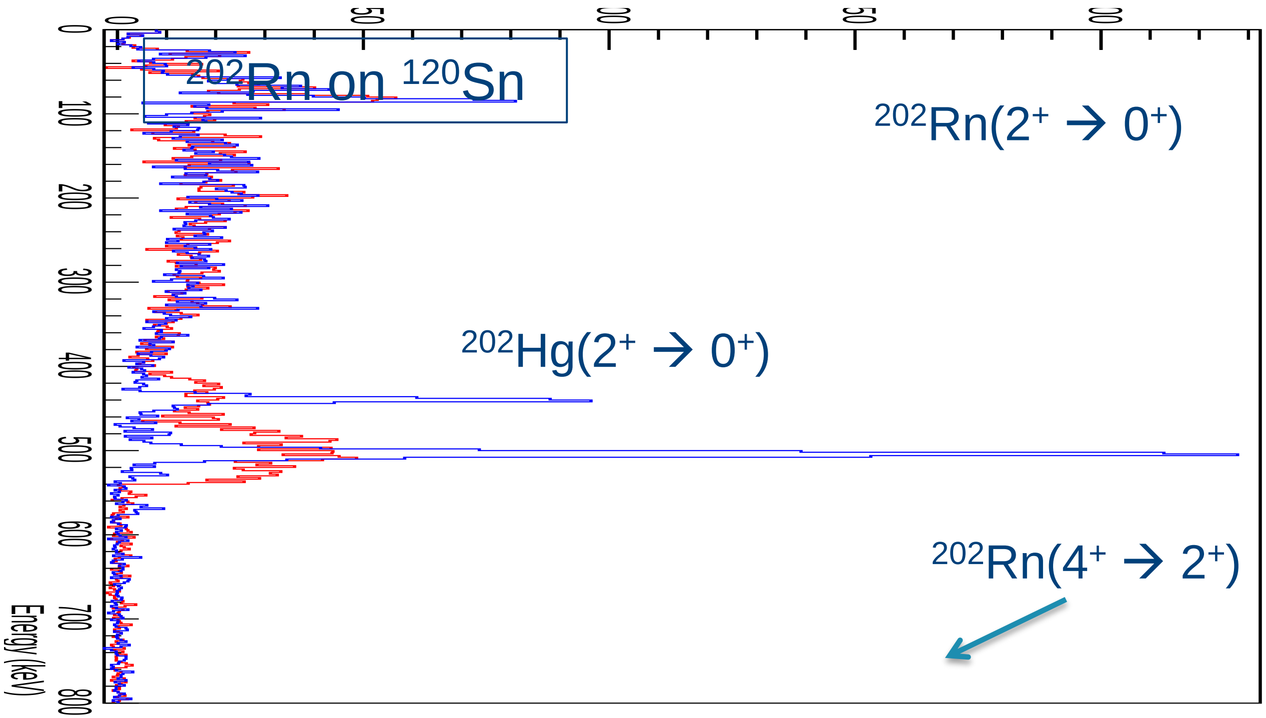


N.Bree et al, in preparation

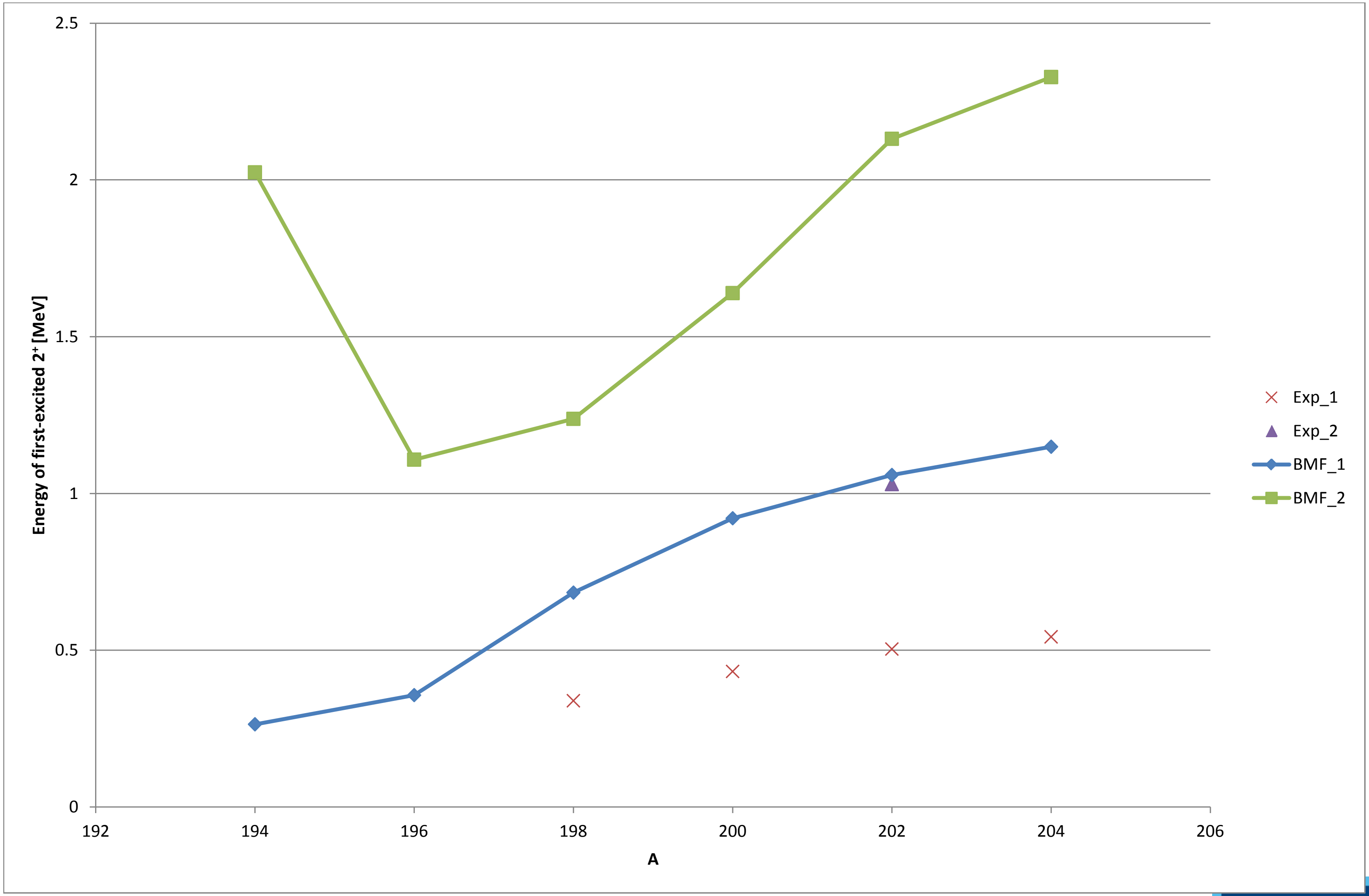
KU LEUVEN

^{202}Hg contamination

- In 2009, cooled transfer line failed allowing Hg out of VADIS.
- Data on Sn target can still be used, normalised to Rn($2^+ \rightarrow 0^+$).
- Data on Ag cannot be reliably normalised yet
  - Subtract Hg related target excitation?

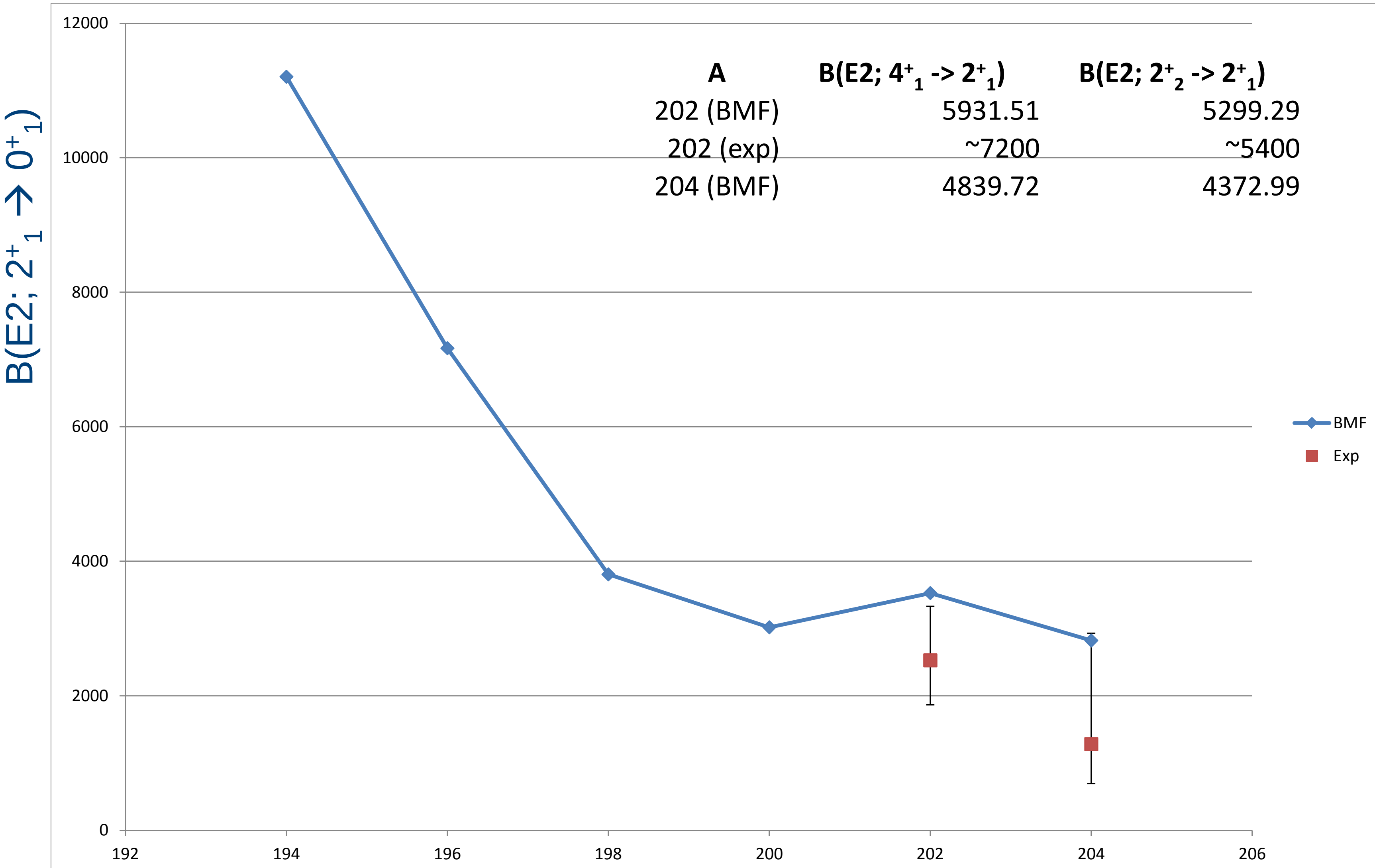


Radon BMF: 2^+ Energies



KU LEUVEN

Radon BMF: B(E2)



A	$B(E2; 4^+_1 \to 2^+_1)$	$B(E2; 2^+_2 \to 2^+_1)$
202 (BMF)	5931.51	5299.29
202 (exp)	~7200	~5400
204 (BMF)	4839.72	4372.99

KU LEUVEN

Radon BMF: $Q_s(2^+)$