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A postcard from Miniball

Latest results and updates from REX-ISOLDE

Liam Gaffney
KU Leuven
on behalf of the Miniball collaboration

BY AIR MAIL
PAR AVION

REX-ISOLDE

EGAN
European Gamma and Ancillary detectors Network

EGAN Workshop 2014, GSI

Outline

- **REX-ISOLDE** overview

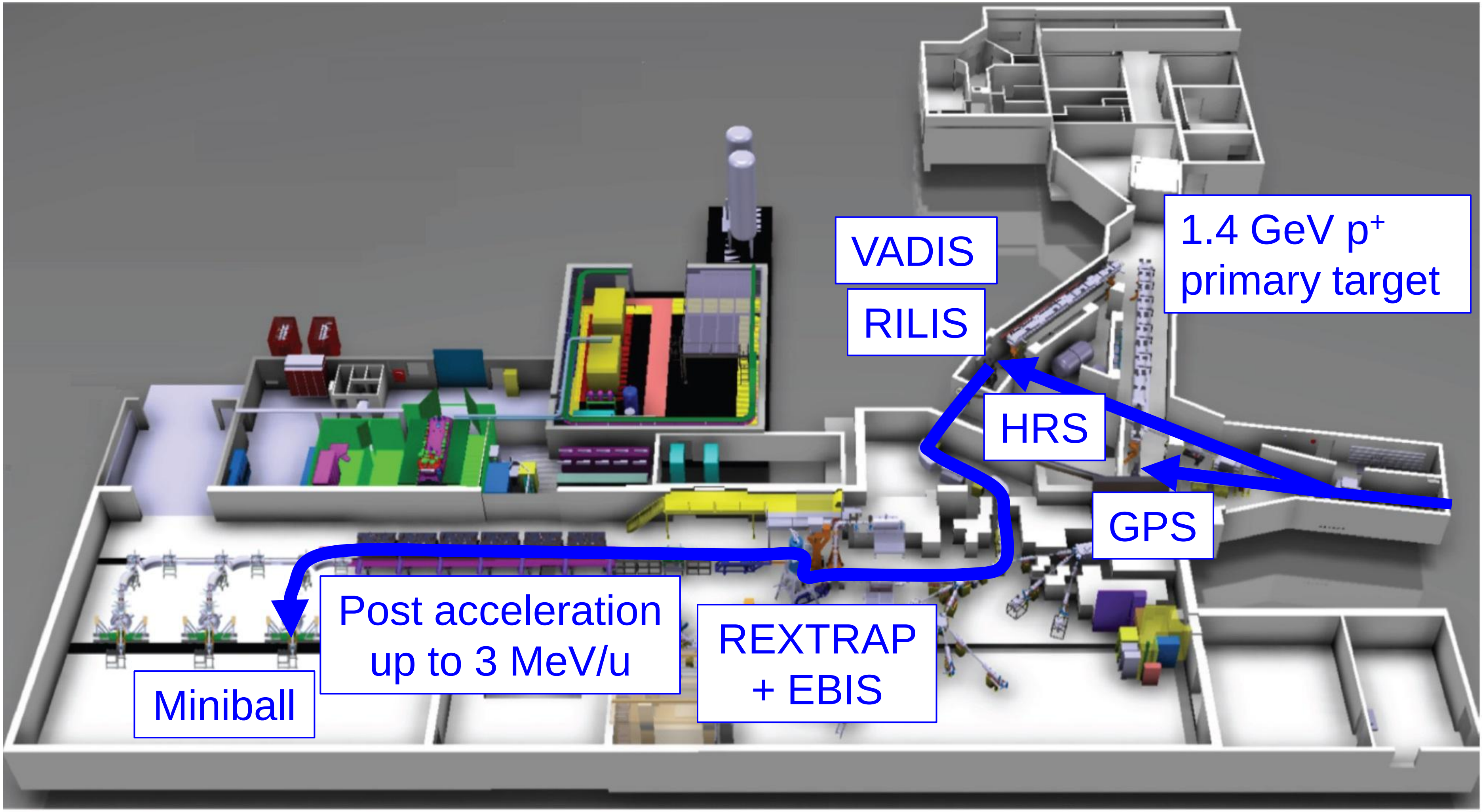
- **Miniball** and its ancillary detector setups
  - CD chamber – Coulex
  - TREX – Transfer
  - SPEDE – electron spectrometer

- Examples of **shell-model physics** experiments
  - 2-neutron transfer into ^{68}Ni

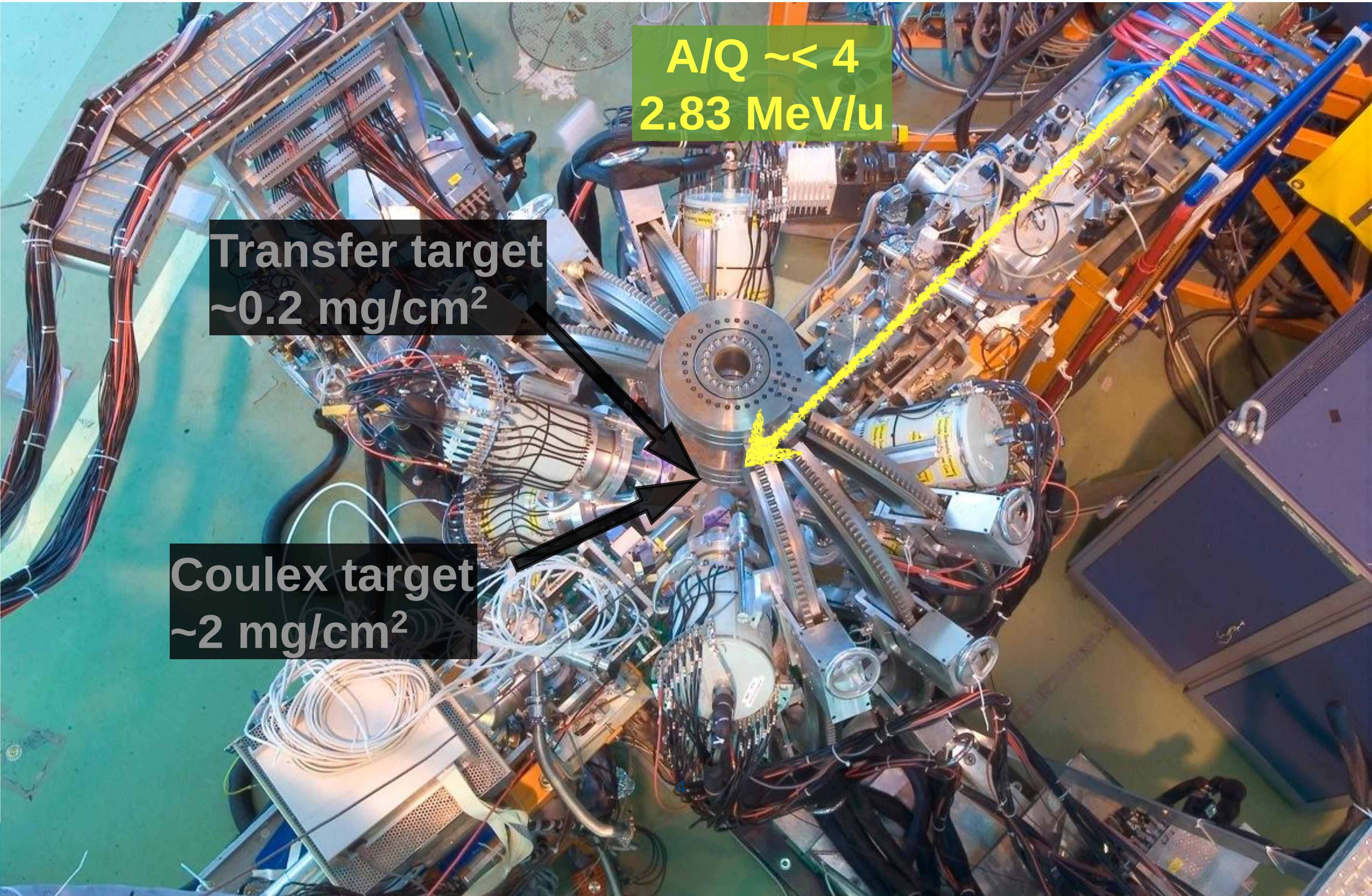
- Examples of experiments studying **collectivity and shapes**
  - Coulex of $^{182\text{-}188}$Hg

- **HIE-ISOLDE** outlook

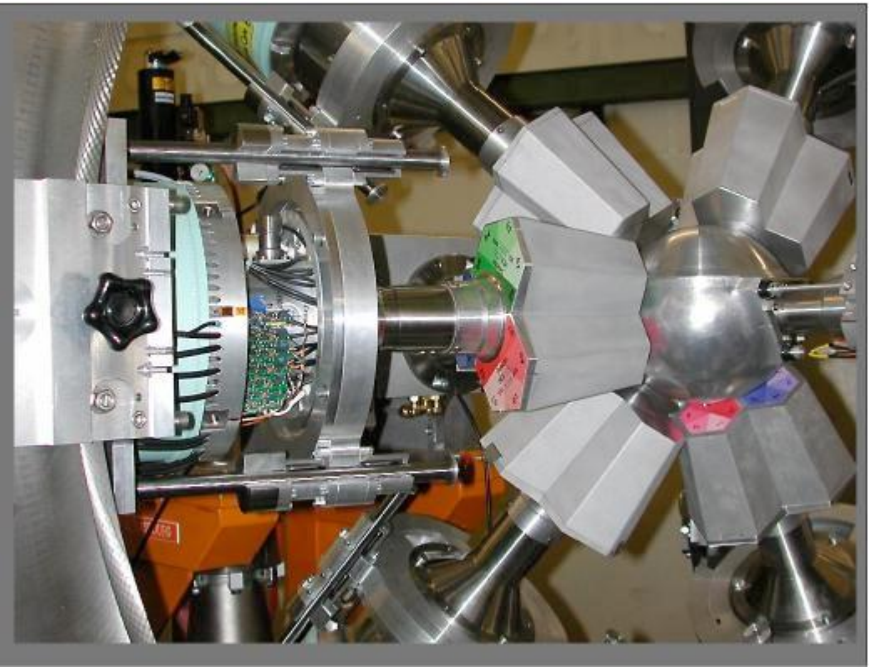
REX-ISOLDE


VADIS
RILIS
1.4 GeV p+
primary target
HRS
GPS
Post acceleration
up to 3 MeV/u
REXTRAP
+ EBIS
Miniball

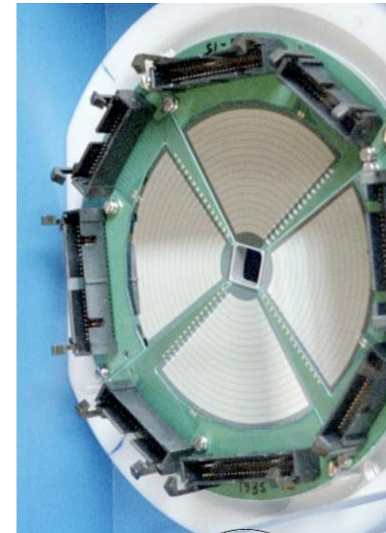
Miniball @ REX-ISOLDE

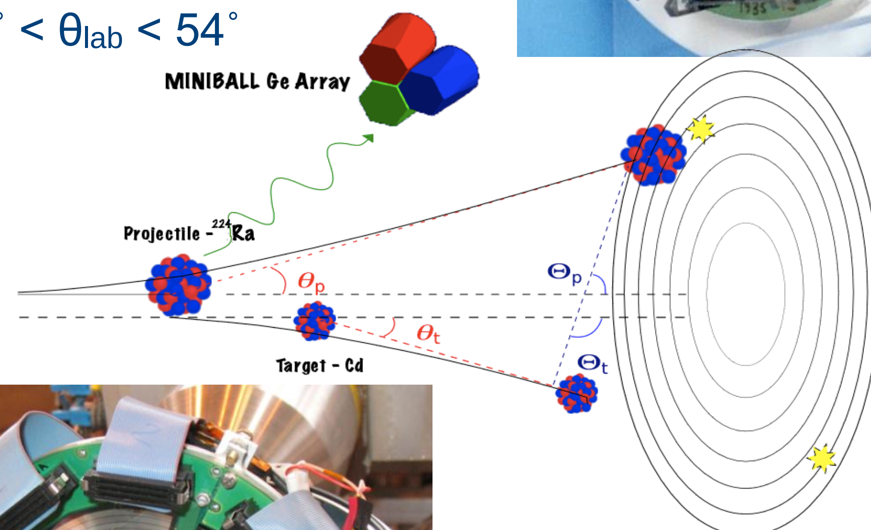


Miniball: Coulex set-up



- Particle ID in a Double-Sided Si Strip Detector.
- Event by event Doppler correction.
- $17^\circ < \theta_{lab} < 54^\circ$





- Array of HPGe of 8 triple clusters
- 6-fold segmentation for positioning
- $\varepsilon > 7\%$ for 1.3MeV γ-rays

N. Warr et al., EPJ **49** (2013)

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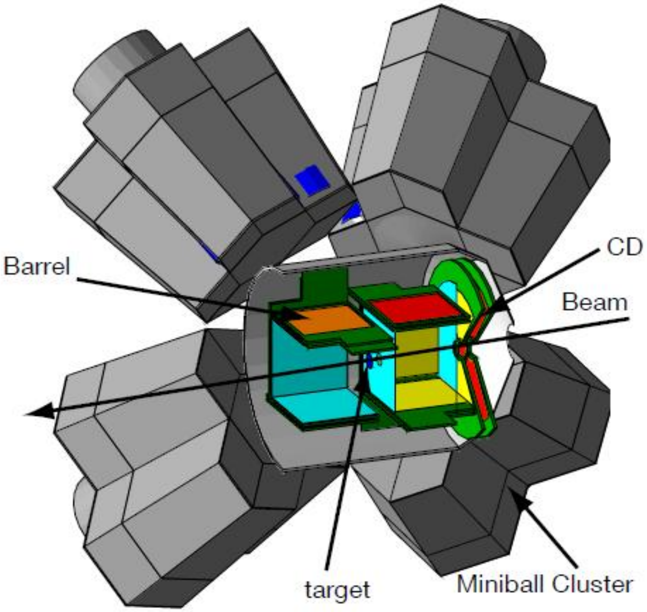
Detector array: TREX

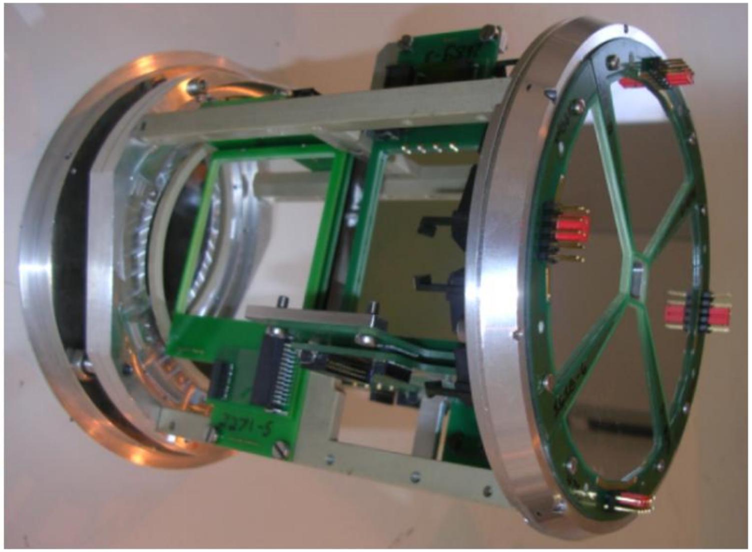
- Charged particle detection in T-REX:
  - Identification (proton, deuteron, alpha…)
  - energy
  - angular distribution

- 8 ΔE-E_{rest} barrel detectors
- 1 ΔE-E_{rest} CD detectors
- Covered θ_{lab} range: 28° to 78° (Forw. Barrel)

  102 to 152° (Back. Barrel)

  152 to 172° (Back. CD)



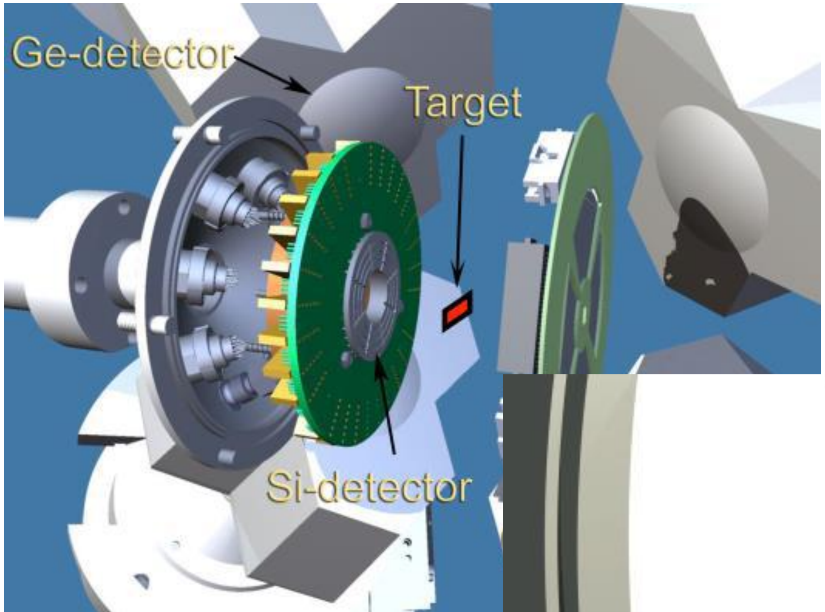


Miniball: Warr EPJ **49** (2013)
T-REX: Bildstein EPJ **48** (2012)

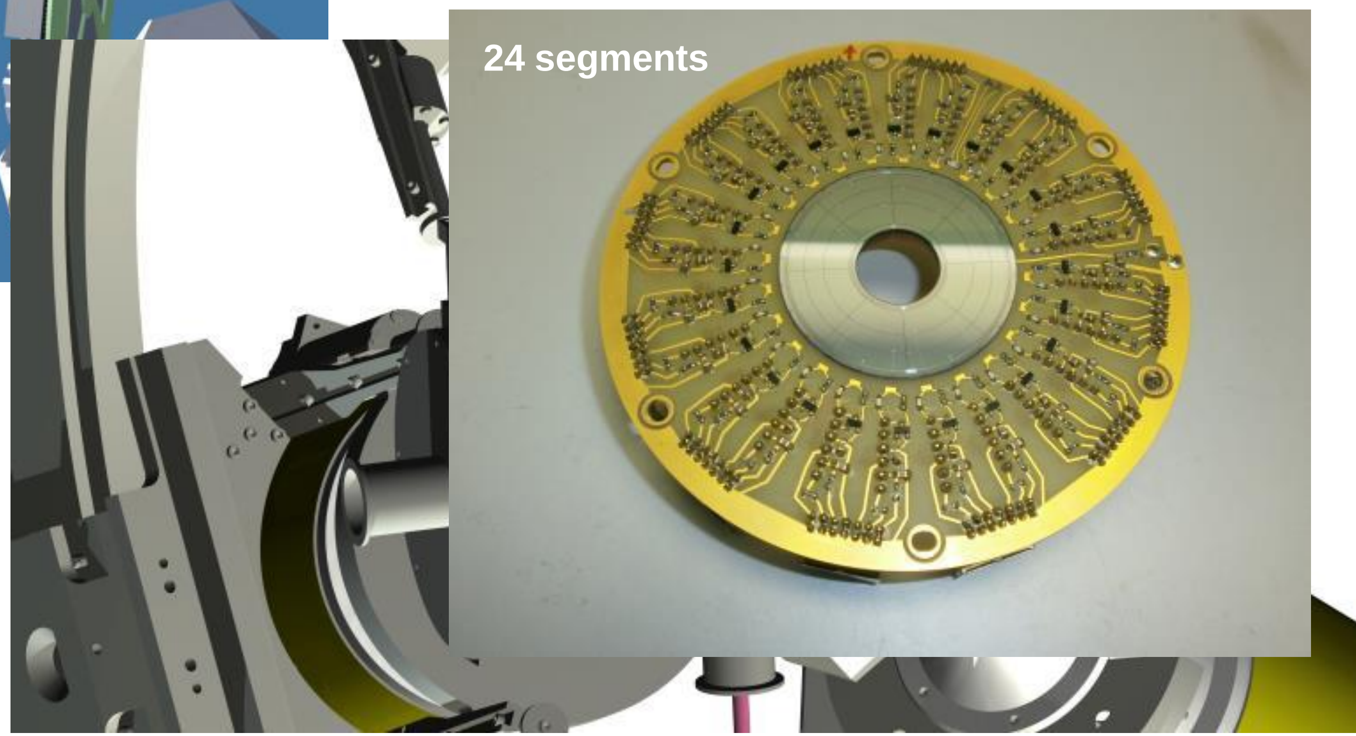
Detector array: SPEDE

UNIVERSITY OF LIVERPOOL

UNIVERSITY OF JYVÄSKYLÄ



- Electron detector placed in backwards direction
- Detection of E0 transitions and conversion electrons
- Key for shape-coexistence studies and odd-mass octupole systems



- New chamber required
- Similar to TREX
- Building/testing begun in Jyväskylä/Liverpool

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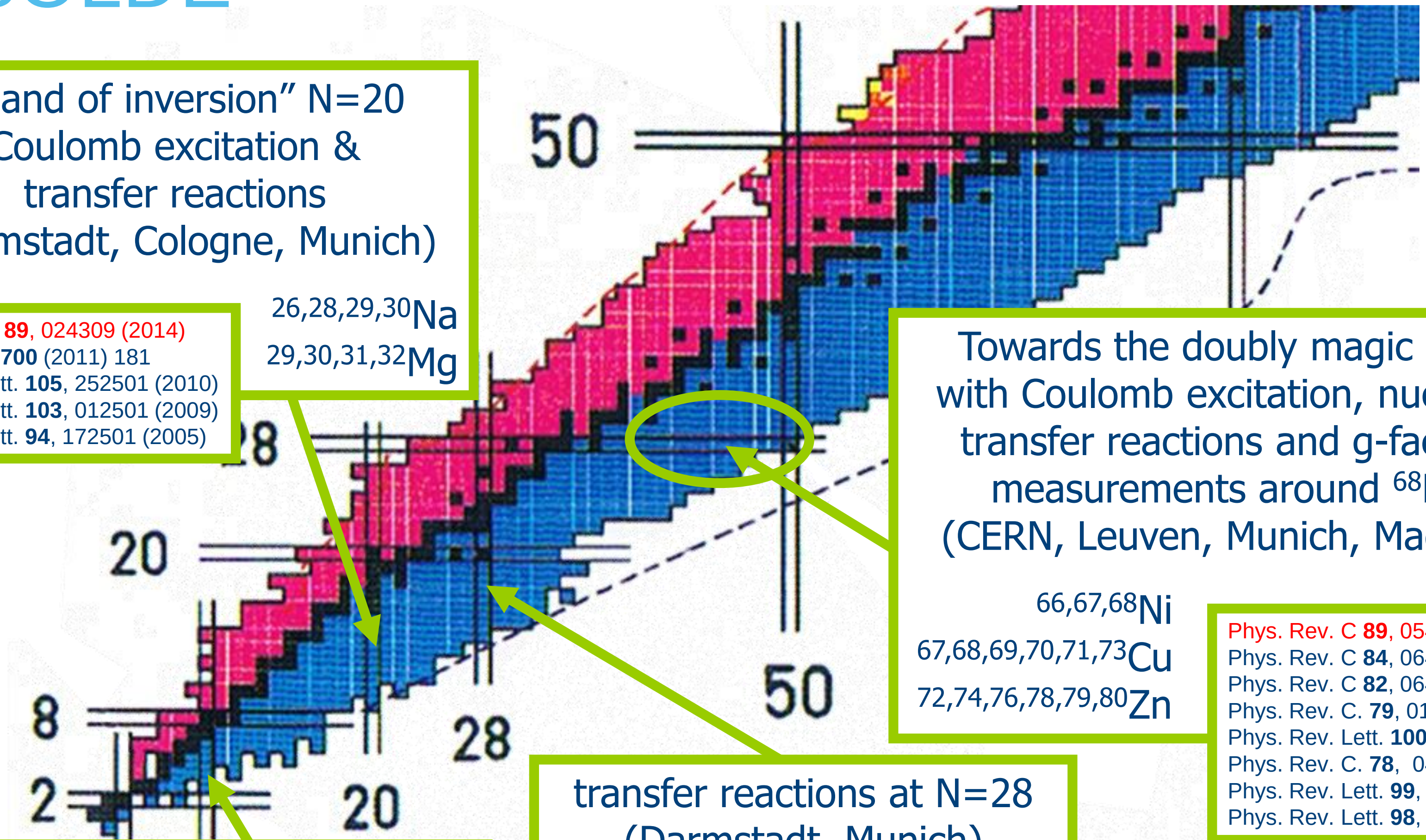
Shell Model Physics with MINIBALL@REX-ISOLDE



"Island of inversion" N=20
Coulomb excitation &
transfer reactions
(Darmstadt, Cologne, Munich)

^{26,28,29,30}Na
^{29,30,31,32}Mg

Phys. Rev. C, **89**, 024309 (2014)
Phys. Lett. B, **700** (2011) 181
Phys. Rev. Lett. **105**, 252501 (2010)
Phys. Rev. Lett. **103**, 012501 (2009)
Phys. Rev. Lett. **94**, 172501 (2005)

Towards the doubly magic ^{78}Ni
with Coulomb excitation, nucleon
transfer reactions and g-factor
measurements around ^{68}Ni
(CERN, Leuven, Munich, Madrid)

^{66,67,68}Ni
^{67,68,69,70,71,73}Cu
^{72,74,76,78,79,80}Zn

Phys. Rev. C **89**, 054316 (2014)
Phys. Rev. C **84**, 064323 (2011)
Phys. Rev. C **82**, 064309 (2010)
Phys. Rev. C. **79**, 014309 (2009)
Phys. Rev. Lett. **100**, 112502 (2008)
Phys. Rev. C. **78**, 047301 (2008)
Phys. Rev. Lett. **99**, 142501 (2007)
Phys. Rev. Lett. **98**, 122701 (2007)

transfer reactions at N=28
(Darmstadt, Munich)

^{46}Ar

The lightest nuclei, transfer
reactions (Aarhus)

^{10,11,12}Be

Phys. Rev. C, **88**, 044619 (2013)

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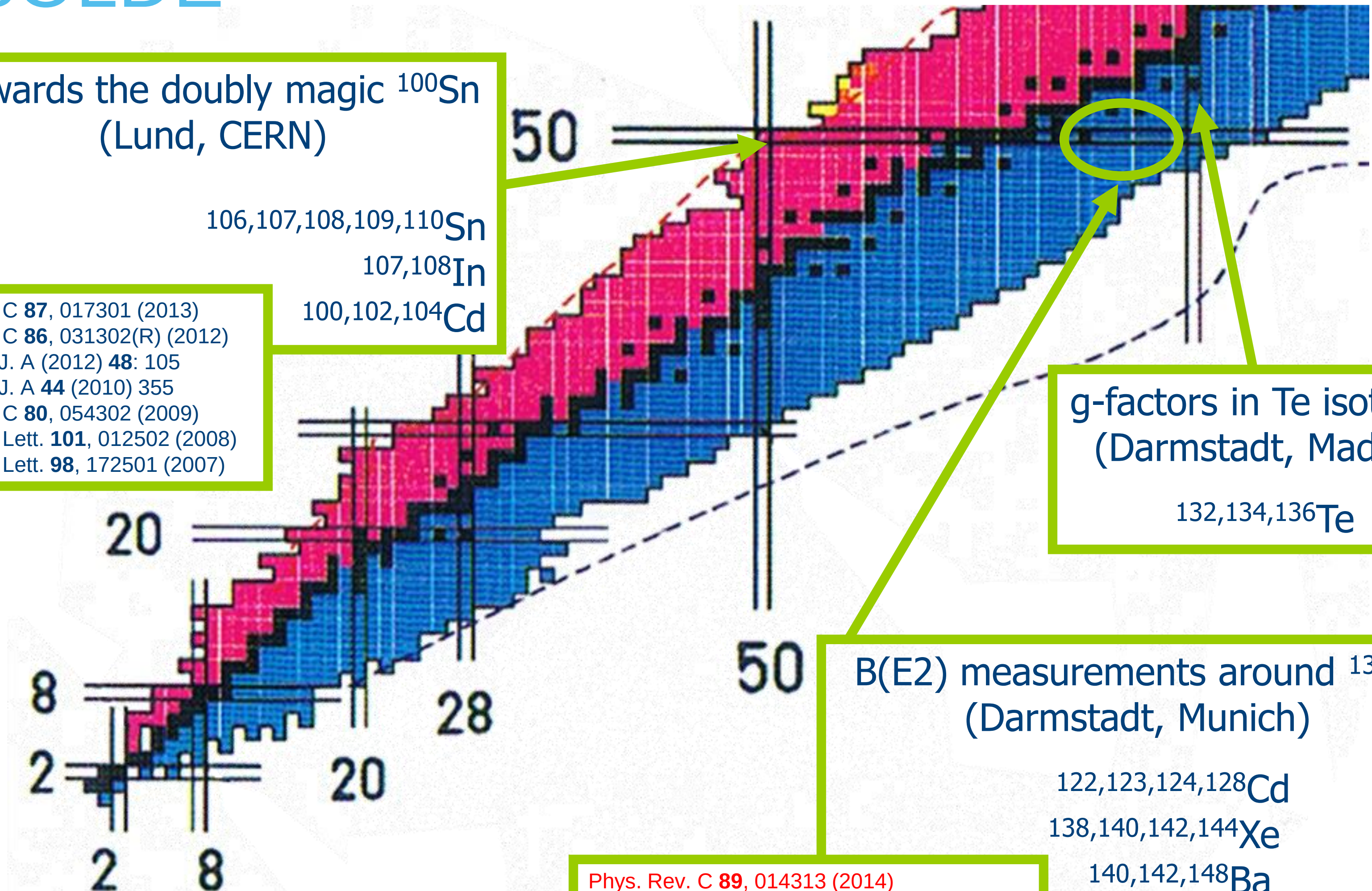
Shell Model Physics with MINIBALL@REX-ISOLDE



Towards the doubly magic ^{100}Sn (Lund, CERN)

^{106,107,108,109,110}Sn
^{107,108}In
^{100,102,104}Cd

Phys. Rev. C **87**, 017301 (2013)
Phys. Rev. C **86**, 031302(R) (2012)
Eur. Phys. J. A (2012) **48**: 105
Eur. Phys. J. A **44** (2010) 355
Phys. Rev. C **80**, 054302 (2009)
Phys. Rev. Lett. **101**, 012502 (2008)
Phys. Rev. Lett. **98**, 172501 (2007)

g-factors in Te isotopes (Darmstadt, Madrid)

^{132,134,136}Te

B(E2) measurements around ^{132}Sn (Darmstadt, Munich)

^{122,123,124,128}Cd
^{138,140,142,144}Xe
^{140,142,148}Ba

Phys. Rev. C **89**, 014313 (2014)
Phys. Rev. C **88**, 021302(R) (2013)
Eur. Phys. J. Special Topics **150**, 127 (2007)

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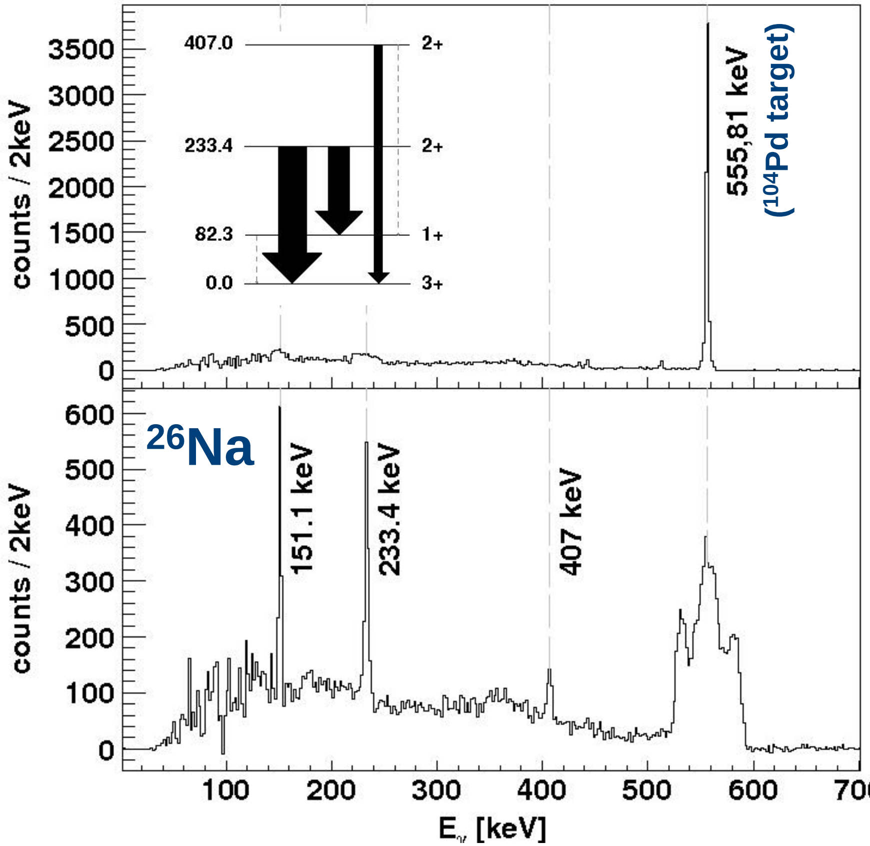
Coulomb excitation of neutron-rich Na nuclei



B. Siebeck *et al.*, PRC, in preparation

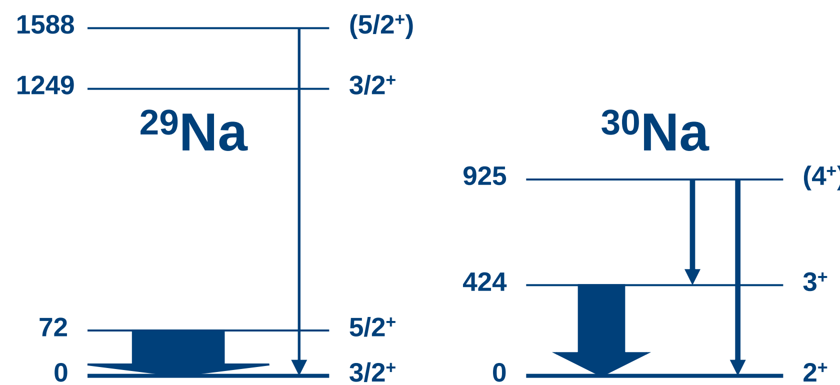
$$B(E2; 2_1^+ \rightarrow 3_1^+) = 12.6^{+0.8}_{-0.4}\ \text{W.u.}$$

$$B(E2; 2_1^+ \rightarrow 1_1^+) = 26^{+24}_{-17}\ \text{W.u.}$$

$$B(E2; 2_2^+ \rightarrow 3_1^+) = 3.2^{+1.1}_{-0.3}\ \text{W.u.}$$

^{29,30}Na: Mapping the borders of the island of inversion

Gradual transition from normal to deformed ground-state configurations in Na confirmed



M. Seidlitz *et al.*, PRC **89**, 024309 (2014)

^{29}Na: $B(E2; 5/2_1^+ \rightarrow 3/2_{gs}^+) = 18.9(25)\ \text{W.u.}$

$B(E2; (5/2_2^+) \rightarrow (3/2_{gs}^+)) < 8.8(50)\ \text{W.u.}$

^{30}Na: $B(E2; 3_1^+ \rightarrow 2_{gs}^+) = 31.3(52)\ \text{W.u.}$

$B(E2; (4_1^+) \rightarrow 2_{gs}^+) = 11.2(35)\ \text{W.u.}$

Verification of shell-model calculations using new USDA/USDB interactions

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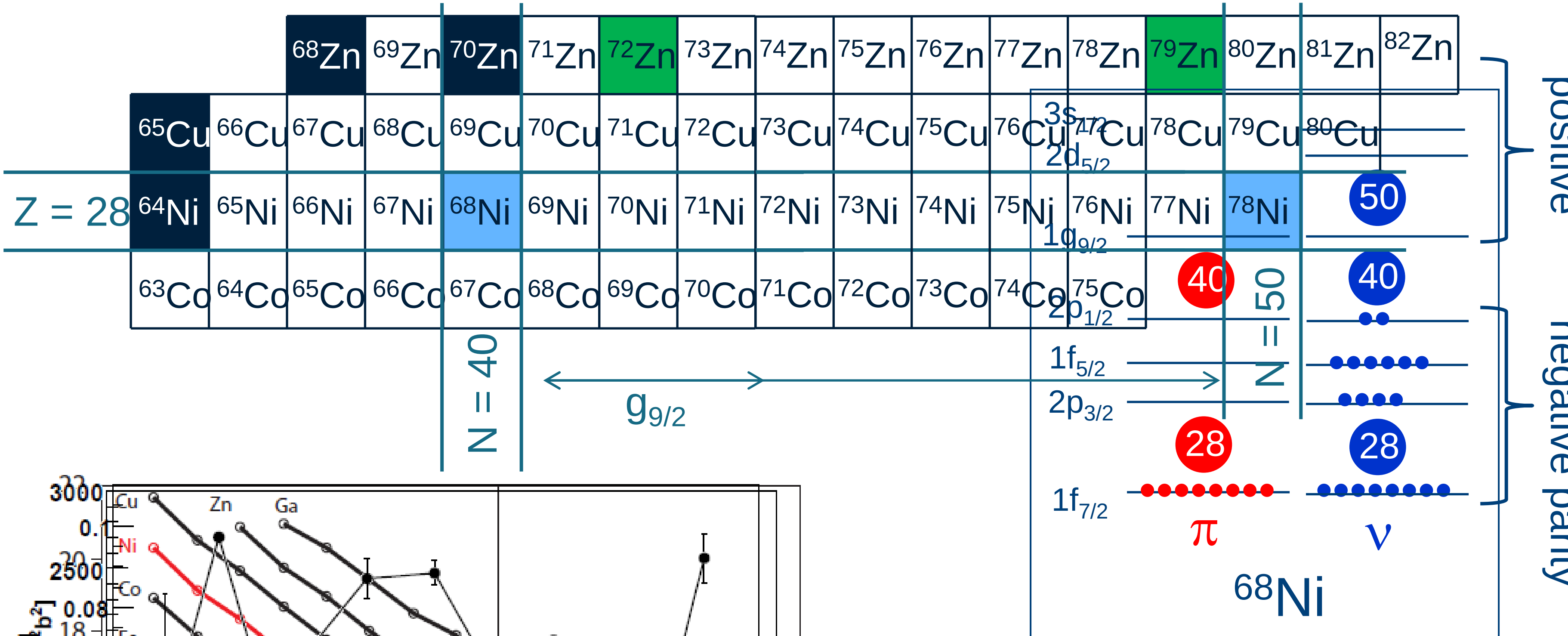
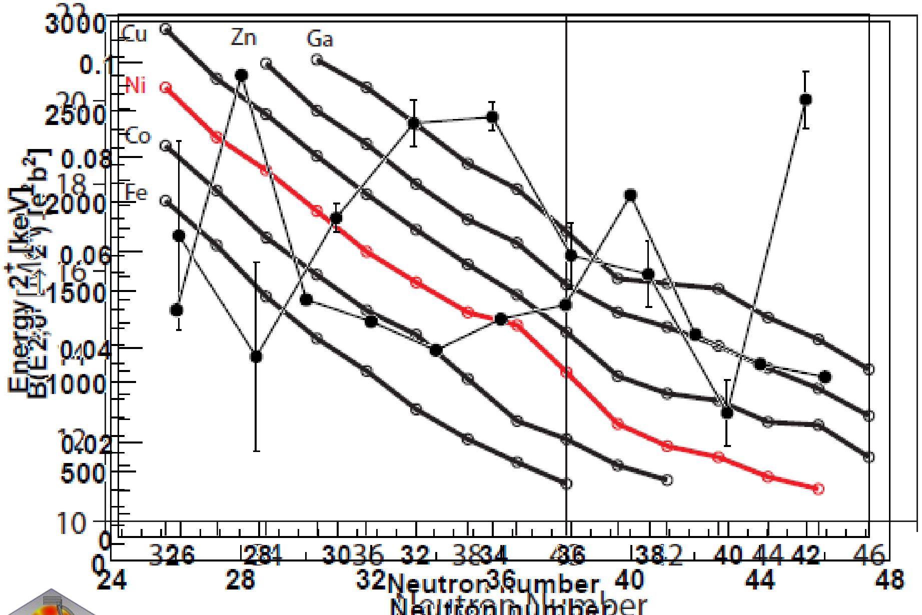
Experimental information around 68Ni





^{68}Ni (Z=28, N=40)

- Maximum in E(2$^+$)
- Local minimum in B(E2)
- No 'kink' in S_{2n}

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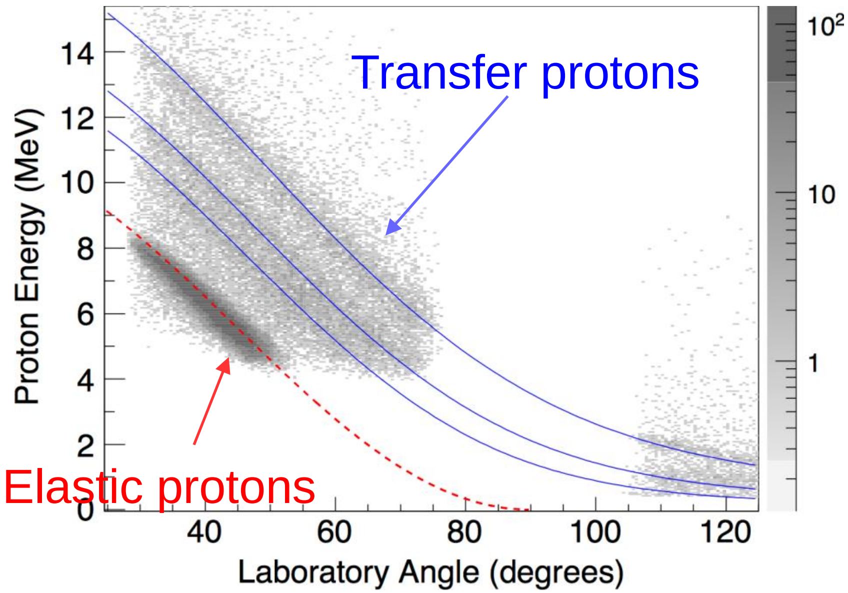
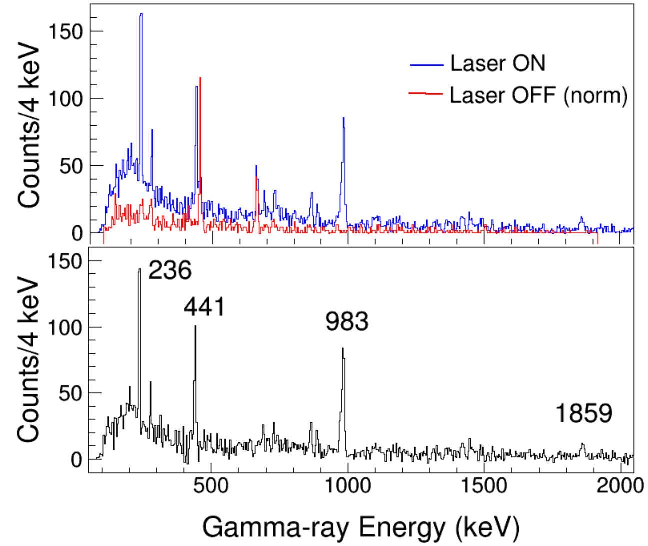
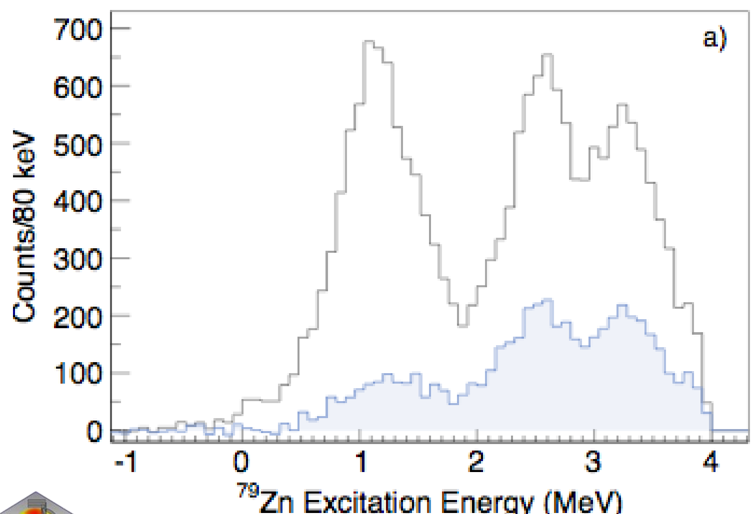
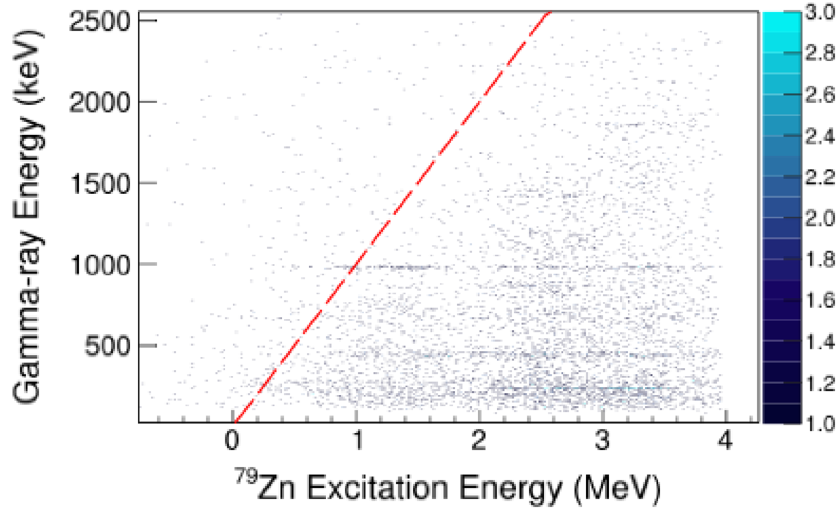
Broda,- PRL **74**, 868 (1995), Sorlin,- PRL **88**, 092501 (2002), Bree,- PRC **78**, 047301 (2008), Bernas,- PLB **113**, 279 (1982), Rahaman,- EPJA **34**:5 (2007), Perru,- PRL **96** 232501 (2006), Langanke,- PRC **90,** 044314 (2003)

^{78}Zn(*d*,*p*)^{79}Zn reaction



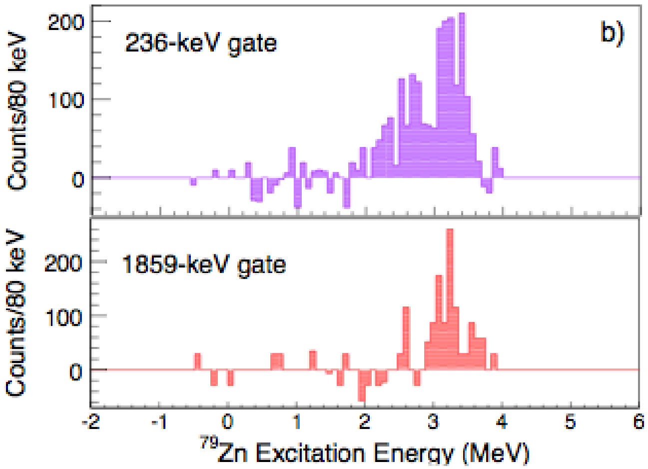


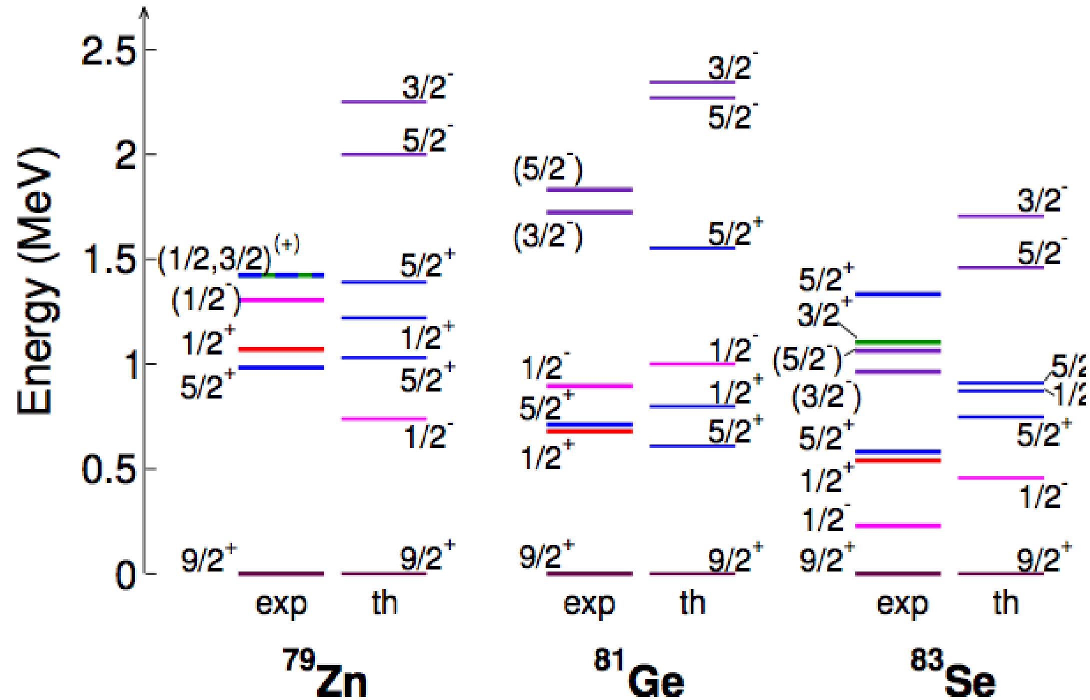


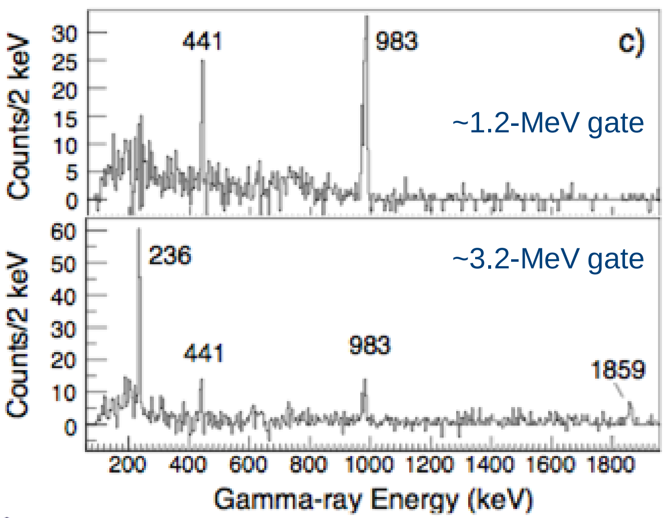


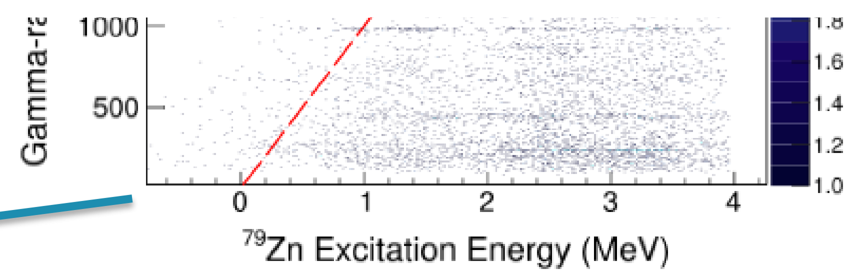
Reconstructed energy:
- from proton events
- from proton-γ coincidences

^{79}Zn – building the level scheme



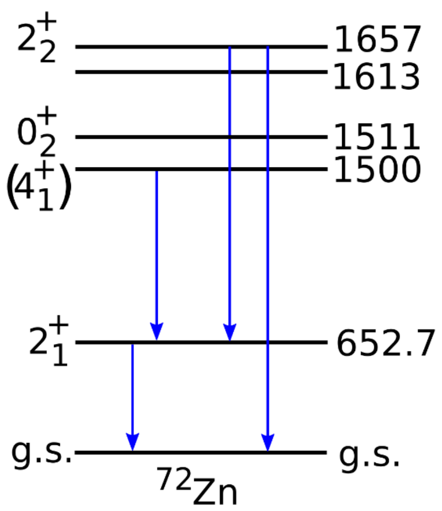




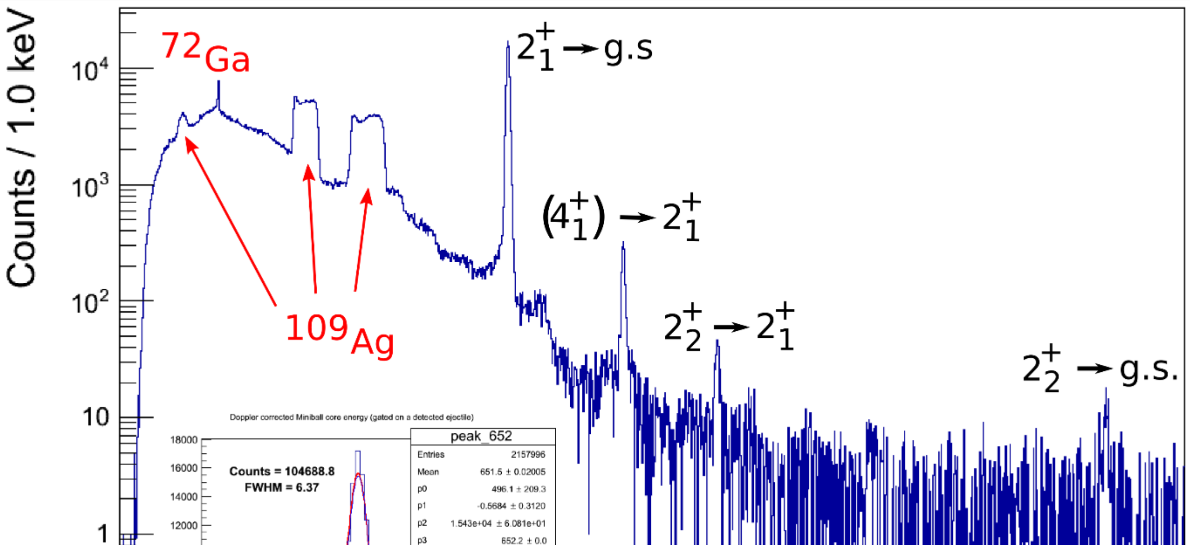


excitation energy gate - reconstruct coincident γ rays

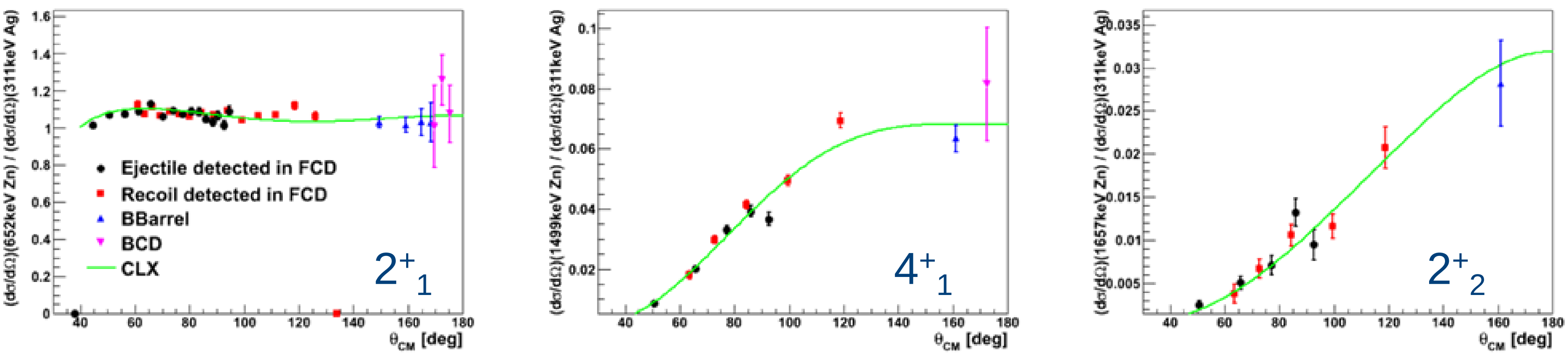
Multiple Coulomb Excitation of ^{72}Zn



Doppler corrected γ-ray spectrum with respect to ^{72}Zn detected in the forward CD



Analysis by Steffi Hellgartner (Munich)

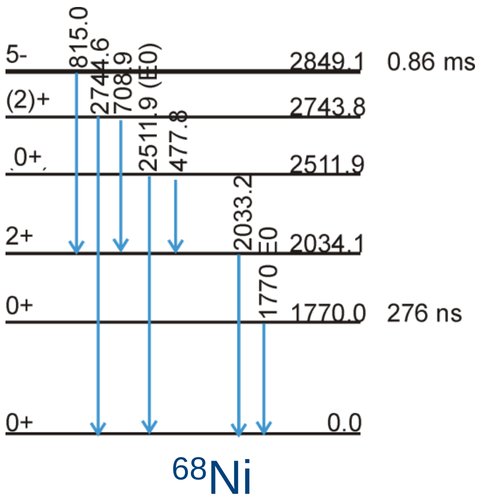


Cross-sections, normalised to ^{109}Ag target excitation….

One- and two neutron transfer reactions around 68Ni

$^{3}H(^{66}Ni,^{68}Ni)^{1}H$

Q = 5.12 MeV

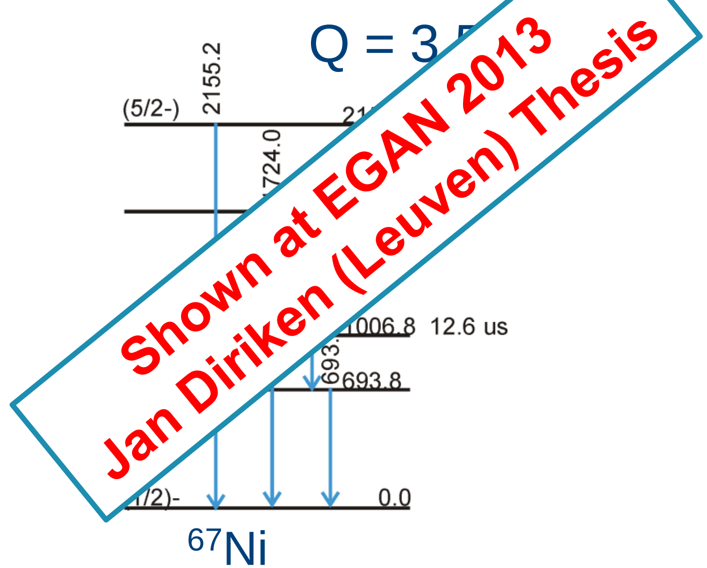


Main aim of experiment:

- Confirm and characterize the 0^+ states

$^{2}H(^{66}Ni,^{67}Ni)^{1}H$

Q = 3.



Main aim of experiment:

- Study the ground state structure (^{68}Ni x ν^{-1})
- Determination of spin and parity of excited states (angular momentum - transfer)
- Identification of $d_{5/2}$ positive parity states (across N=50)

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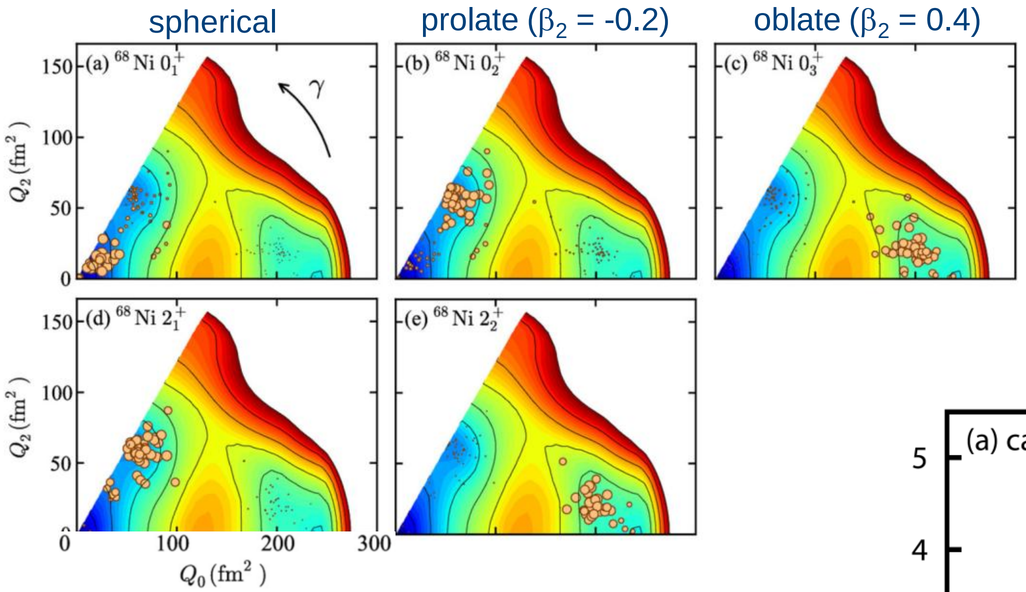
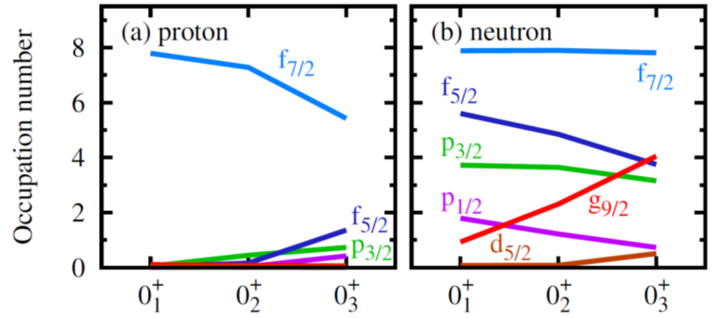
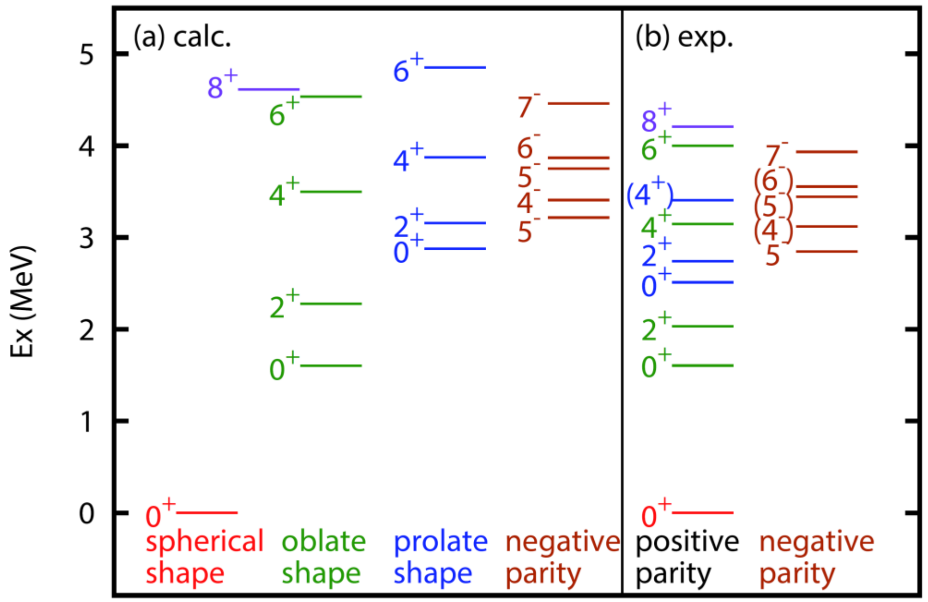
Monte Carlo Shell model calculations ^{68}Ni







^{68}Ni

Y. Tsunoda et al. PRC 89 031301 (2013)

- Type II shell evolution (within same nucleus)
- Full pf + $1g_{9/2}$ + $2d_{5/2}$ for both neutrons and protons

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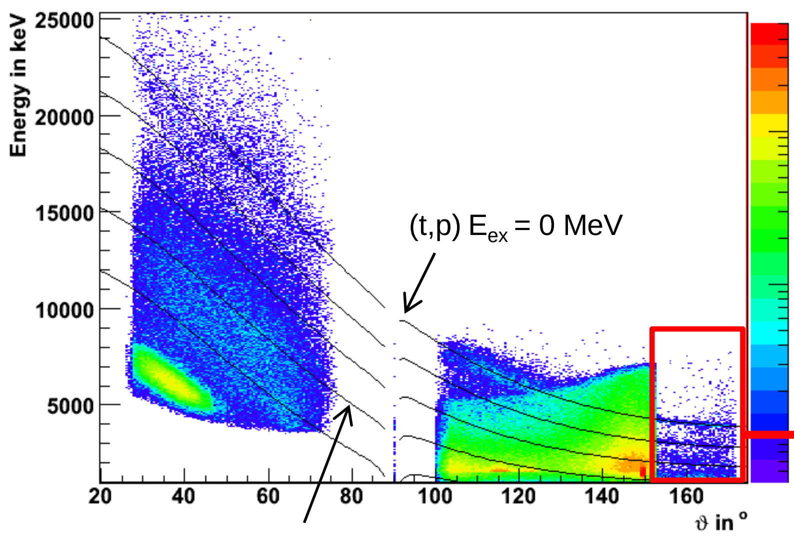
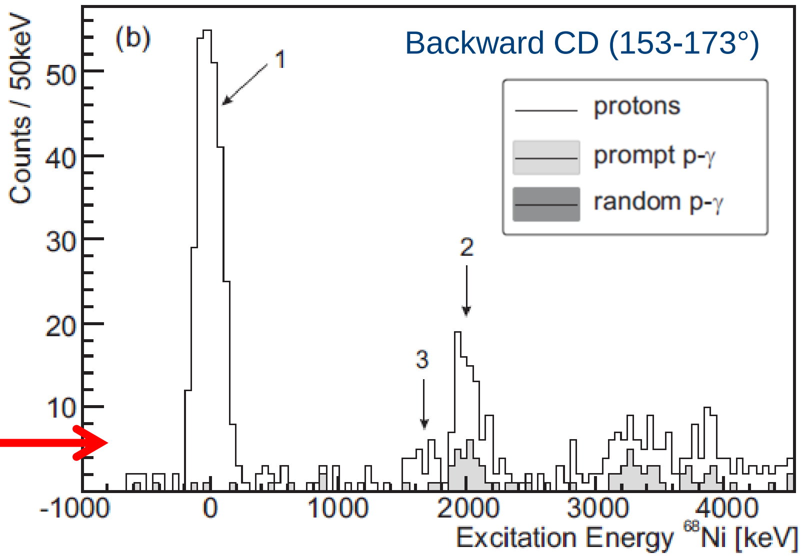
$^3H(^{66}Ni,p)^{68}Ni$: Backward CD





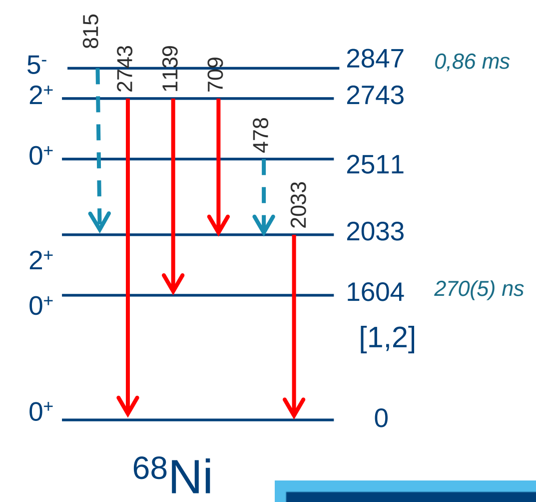
CD data only (before beam tuning)

- **Population of 0_2^+ and 2^+_1 states (relative to gs)**

  E = 1621(28) keV - 4.8(16) % of gs
  E = 2033(10) keV - 29(3) % of gs

- **Non-observed direct population of 0_3^+ , 2_2^+ and 2^+_3 states**

0^+_3 (2512 keV) < 2%		based on 478 keV transition
2^+_2 (2744 keV) < 4%		based on 709 keV transition
2^+_3 (4026 keV) < 3%		based on 1515 keV transition



[1] Recchia et al PRC **88** 041302 (2013)
[2] Sutchya et al PRC **89** 021301 (2014)

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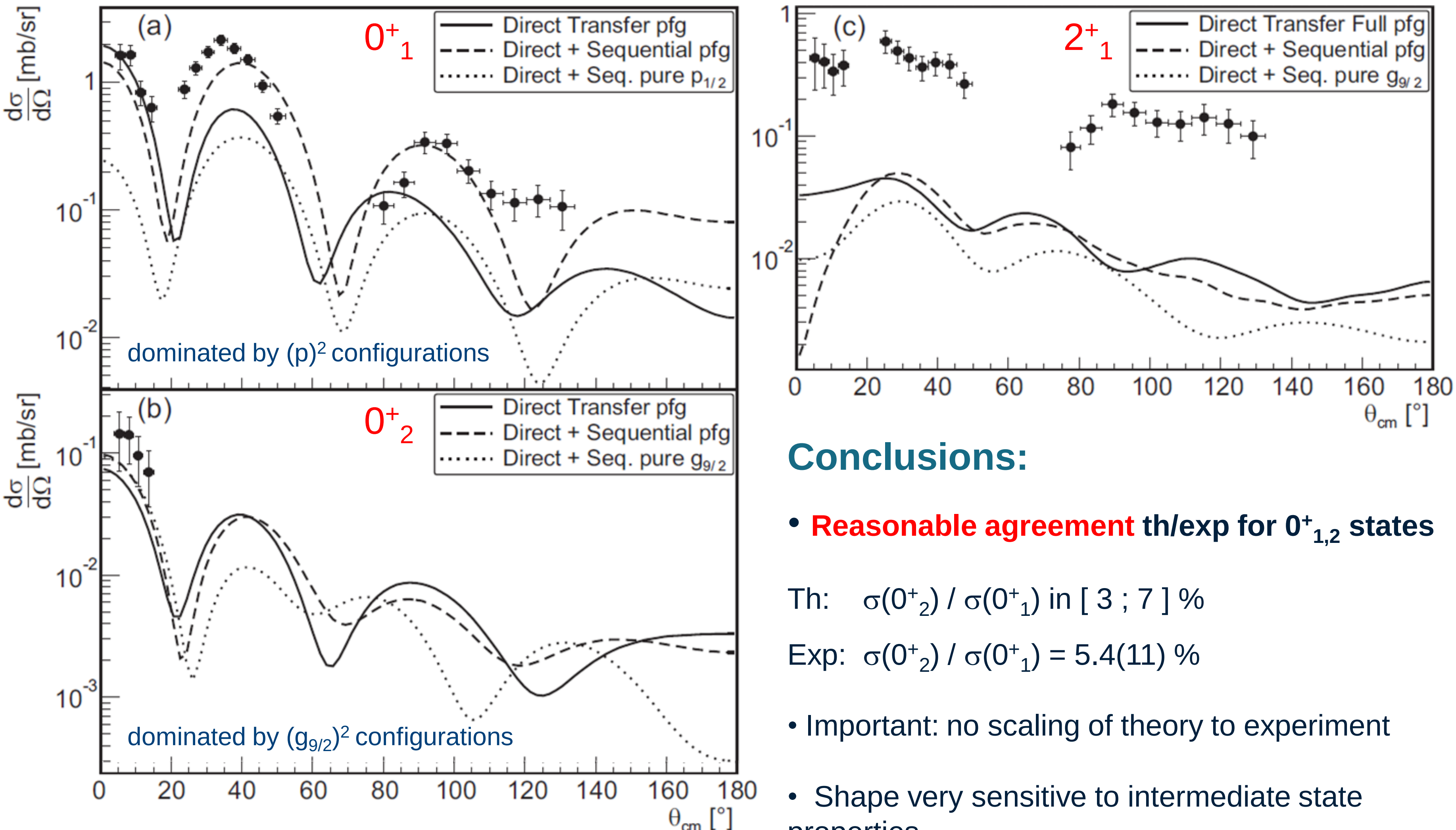
$^{66}Ni(^3H,p)^{68}Ni$: Angular distributions



NuShell calculations with jj44pna interaction

Conclusions:

- **Reasonable agreement th/exp for $0^+_{1,2}$ states**

Th: $\sigma(0^+_2) / \sigma(0^+_1)$ in [3 ; 7] %

Exp: $\sigma(0^+_2) / \sigma(0^+_1) = 5.4(11)$ %

- Important: no scaling of theory to experiment

- Shape very sensitive to intermediate state properties

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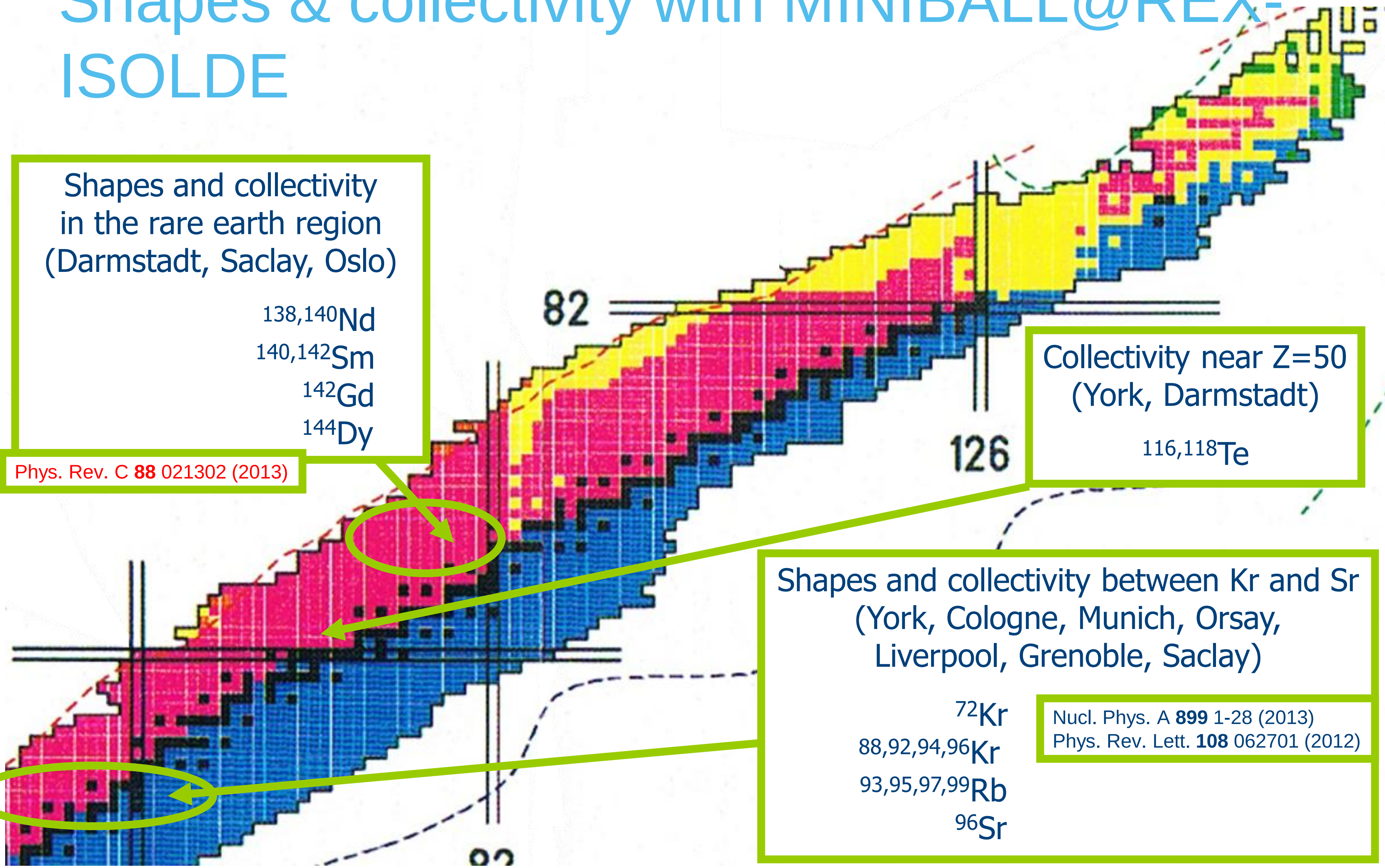
Shapes & collectivity with MINIBALL@REX-ISOLDE



Shapes and collectivity in the rare earth region (Darmstadt, Saclay, Oslo)

^{138,140}Nd
^{140,142}Sm
^{142}Gd
^{144}Dy

Phys. Rev. C **88** 021302 (2013)

Collectivity near Z=50 (York, Darmstadt)

^{116,118}Te

Shapes and collectivity between Kr and Sr (York, Cologne, Munich, Orsay, Liverpool, Grenoble, Saclay)

^{72}Kr
^{88,92,94,96}Kr
^{93,95,97,99}Rb
^{96}Sr

Nucl. Phys. A **899** 1-28 (2013)
Phys. Rev. Lett. **108** 062701 (2012)

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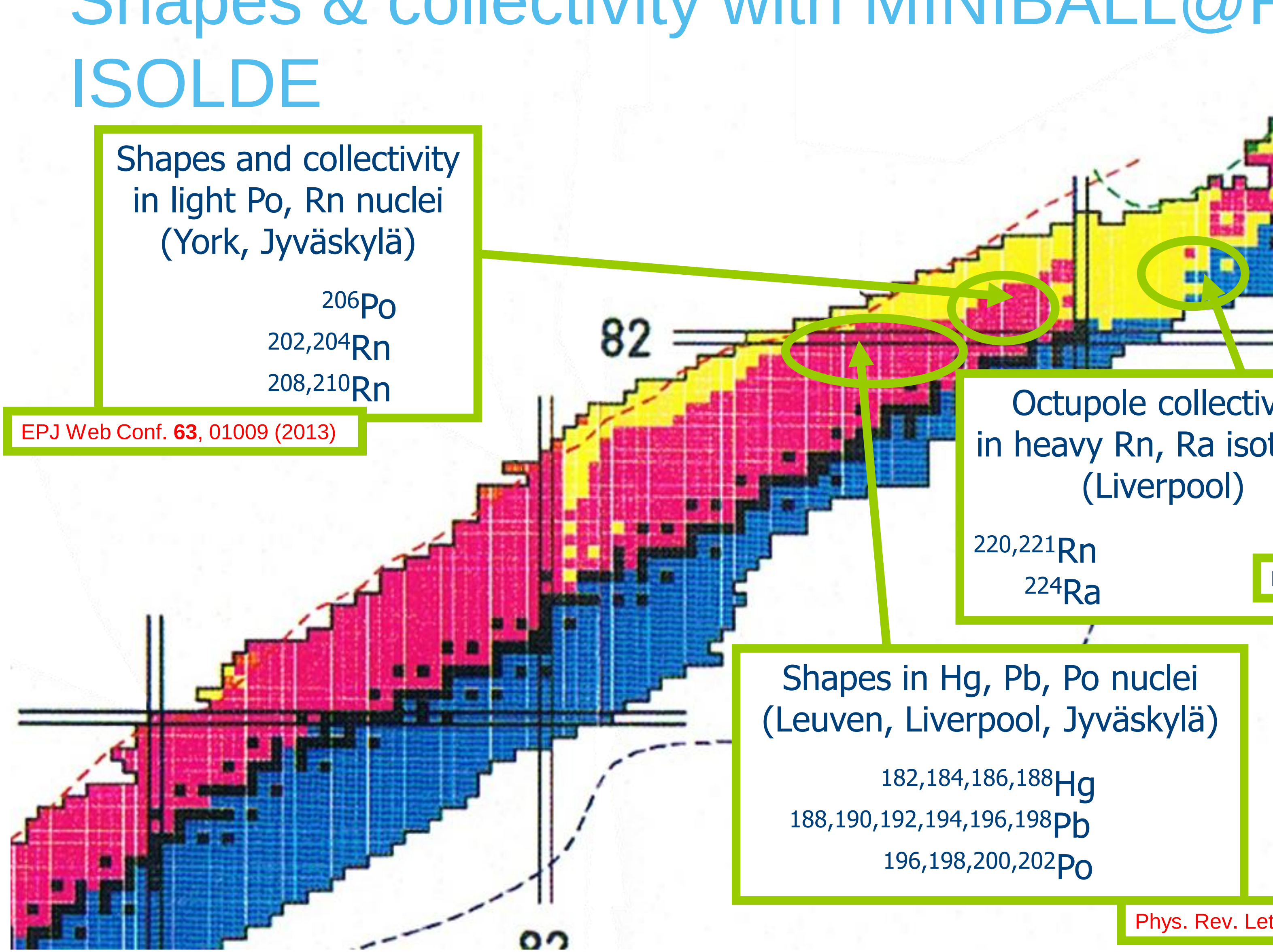
Shapes & collectivity with MINIBALL@REX-ISOLDE



Shapes and collectivity in light Po, Rn nuclei (York, Jyväskylä)

^{206}Po
^{202,204}Rn
^{208,210}Rn

EPJ Web Conf. **63**, 01009 (2013)

Octupole collectivity in heavy Rn, Ra isotopes (Liverpool)

^{220,221}Rn
^{224}Ra

Nature **497** (2013) 199

Shapes in Hg, Pb, Po nuclei (Leuven, Liverpool, Jyväskylä)

^{182,184,186,188}Hg
^{188,190,192,194,196,198}Pb
^{196,198,200,202}Po

Phys. Rev. Lett. **112** 162701 (2014)

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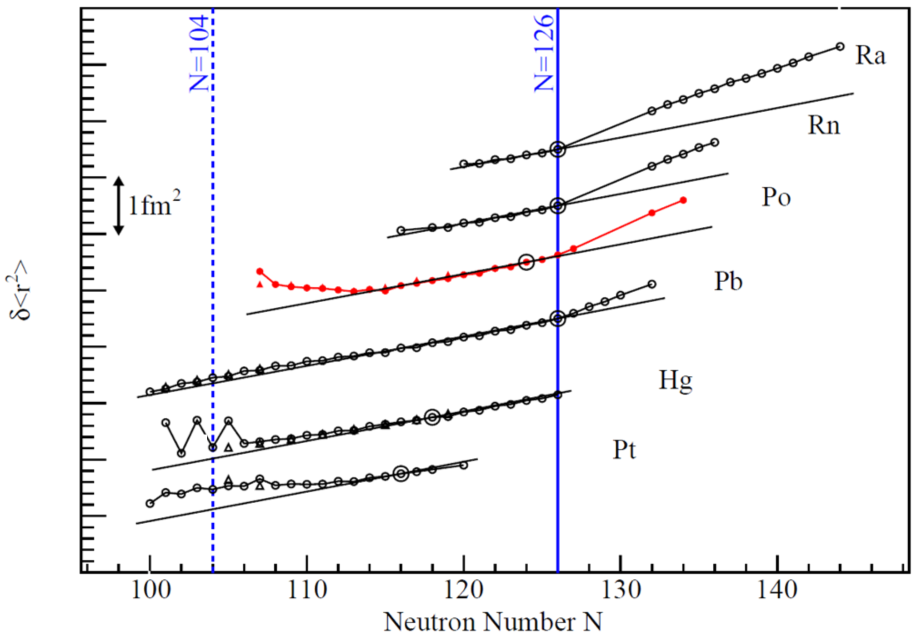
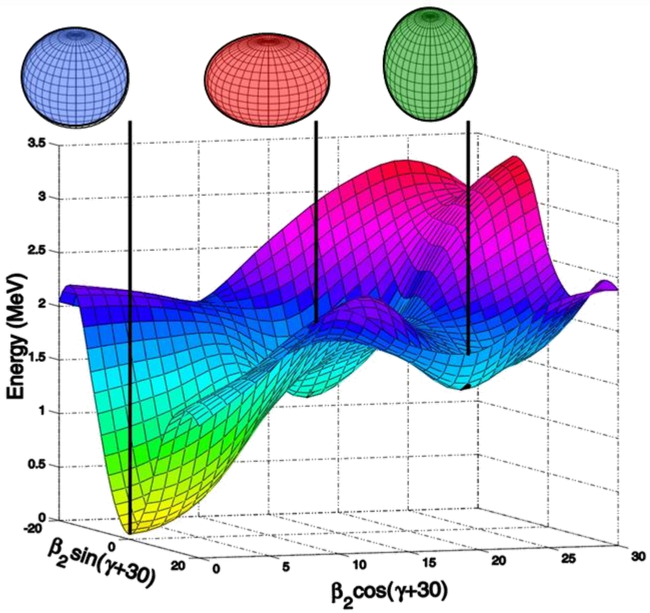
Shape coexistence

- Different types of deformation at low excitation energy
- Interplay between two opposing tendencies
  - Stabilizing effect of closed shells
  - Residual proton-neutron interaction

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

- Also appears in other regions of the nuclear chart, e.g. 72Kr → Nara Singh's talk next!

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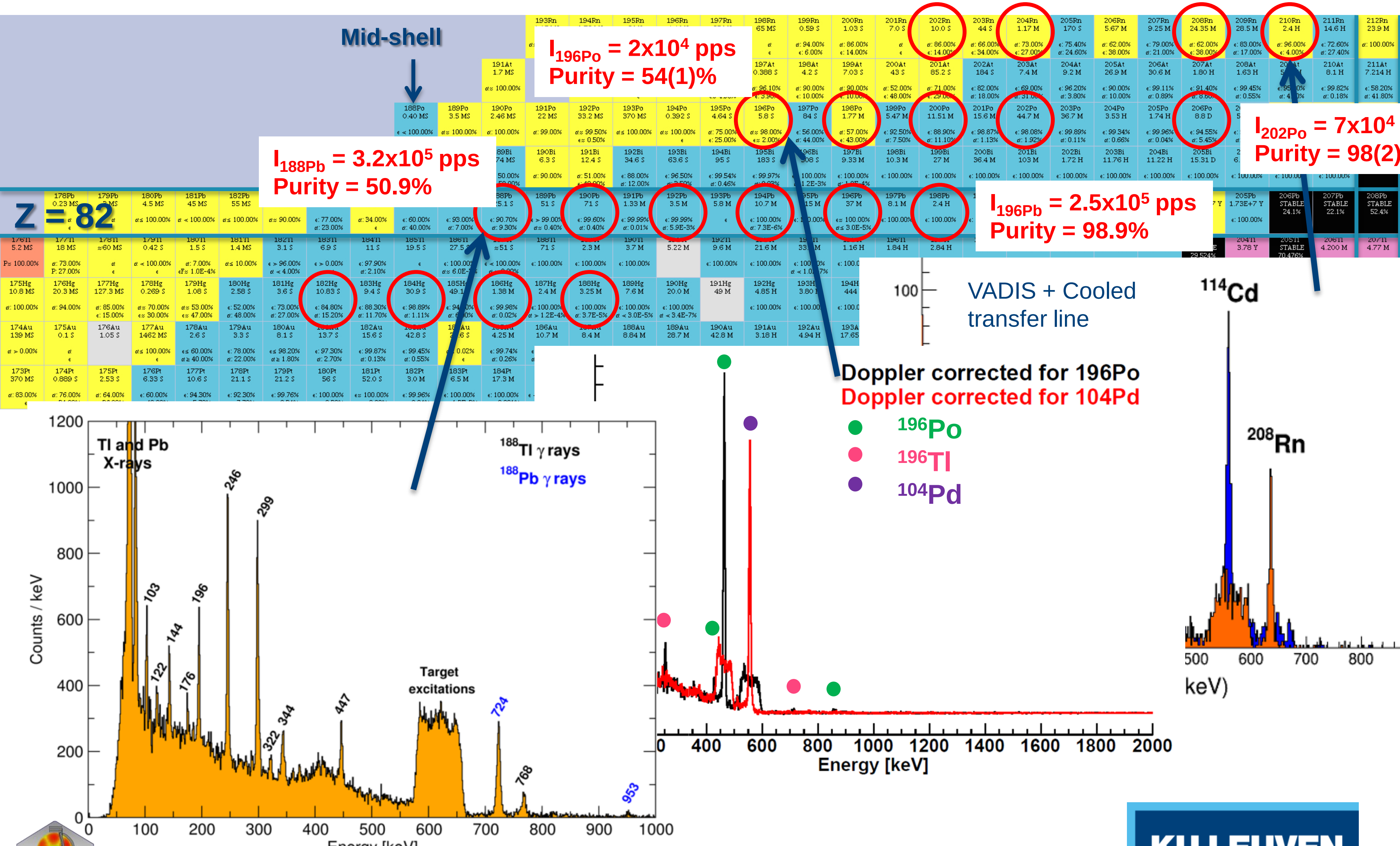
Experimental program in the Pb region



$^{188-196}$Pb: Janne Pakarinen (Jyväskylä)

^{206}Po, ^{208,210}Rn: Tuomas Grahn(Jyväskylä)

$^{196-202}$Po: Nele Kesteloot (Leuven)

$^{182-188}$Hg: Nick Bree (Leuven) & Andrew Petts (Liverpool)

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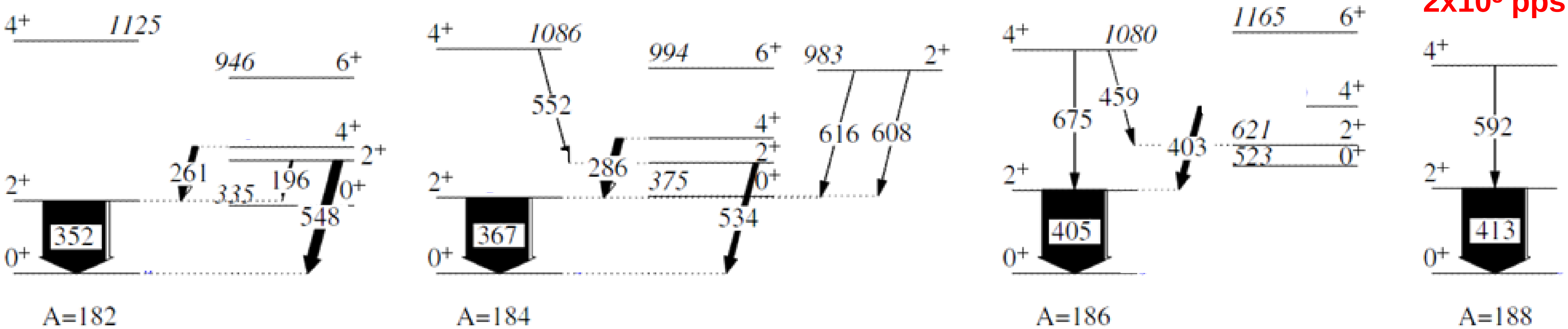
Z = 80: $^{182\text{-}188}$Hg

I_{182Hg} = 4x10³ pps

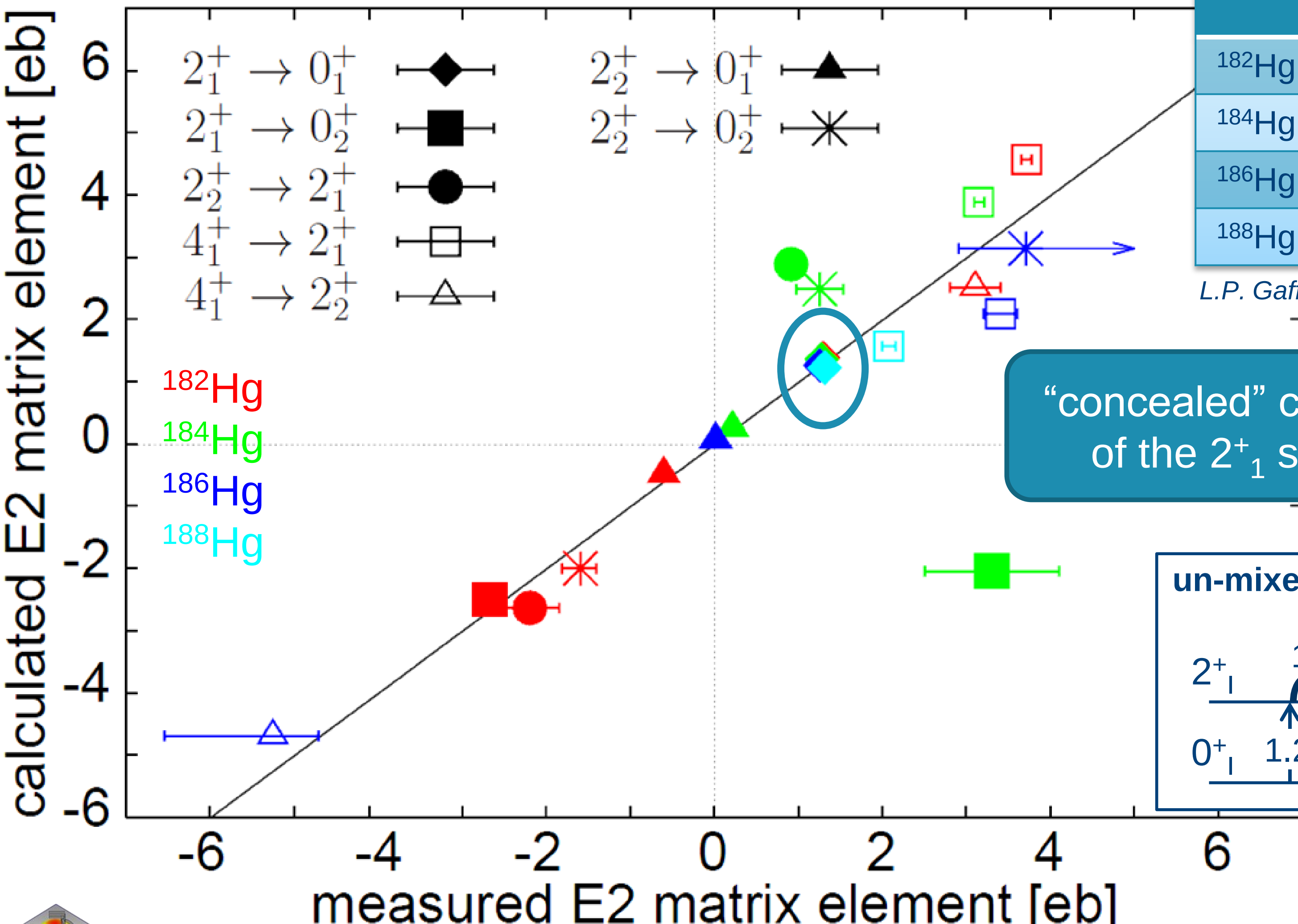
I_{188Hg} = 2x10⁵ pps



$\langle I_i \Vert E2 \Vert I_f \rangle$ (eb)	^{182}Hg	^{184}Hg	^{186}Hg	^{188}Hg
$\langle 0_1^+ \Vert E2 \Vert 2_1^+ \rangle$	$1.29^{+0.04}_{-0.03}$	1.27 (3)	$1.25^{+0.10}_{-0.07}$	1.31 (10)
$\langle 2_1^+ \Vert E2 \Vert 4_1^+ \rangle$	3.71 (6)	3.15 (6)	3.4 (2)	2.07(8)
$\langle 0_1^+ \Vert E2 \Vert 2_2^+ \rangle$	−0.61 (3)	0.21 (2)	(±) 0.05 (1)	
$\langle 0_2^+ \Vert E2 \Vert 2_1^+ \rangle$	$-2.68^{+0.15}_{-0.13}$	3.3 (8)		
$\langle 0_2^+ \Vert E2 \Vert 2_2^+ \rangle$	−1.7 (2)	1.25 (28)	≥ 3.7 (8)	
$\langle 2_1^+ \Vert E2 \Vert 2_2^+ \rangle$	−2.2 (4)	0.91 (14)		
$\langle 2_2^+ \Vert E2 \Vert 4_1^+ \rangle$	3.1 (3)	5.8 (5)	$-5.3^{+1.3}_{-0.5}$	
$\langle 2_1^+ \Vert E2 \Vert 2_1^+ \rangle$	$-0.04^{+1.30}_{-1.40}$	$1.5^{+1.8}_{-1.2}$		$1.0^{+0.6}_{-0.4}$
$\langle 2_2^+ \Vert E2 \Vert 2_2^+ \rangle$	$0.8^{+1.0}_{-0.6}$	−2.6 (20)		

N. Bree et al, PRL **112** 162701 (2014)

Interpretation with two-level mixing model

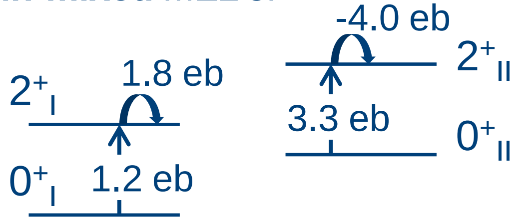


	α_{0+}^2	α_{2+}^2	α_{4+}^2
^{182}Hg	92%	29%	3%
^{184}Hg	95%	51%	4%
^{186}Hg	98%	90%	7%
^{188}Hg	99%	98%	20%

L.P. Gaffney et al, PRC 89, 024307 (2014)

"concealed" configuration mixing of the 2^+_1 states of $^{182-188}Hg$

un-mixed ME2's:



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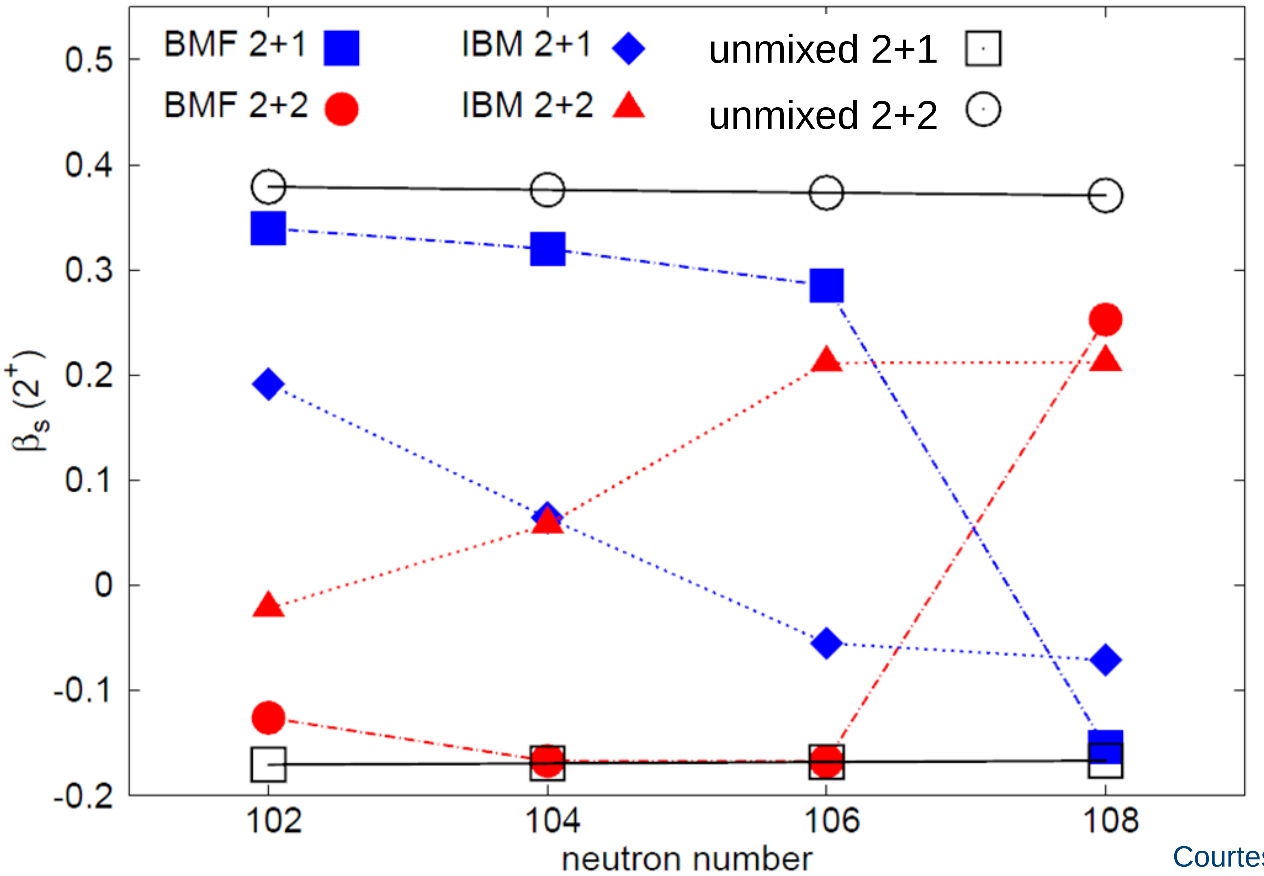
Comparison to theory – IBM and BMF

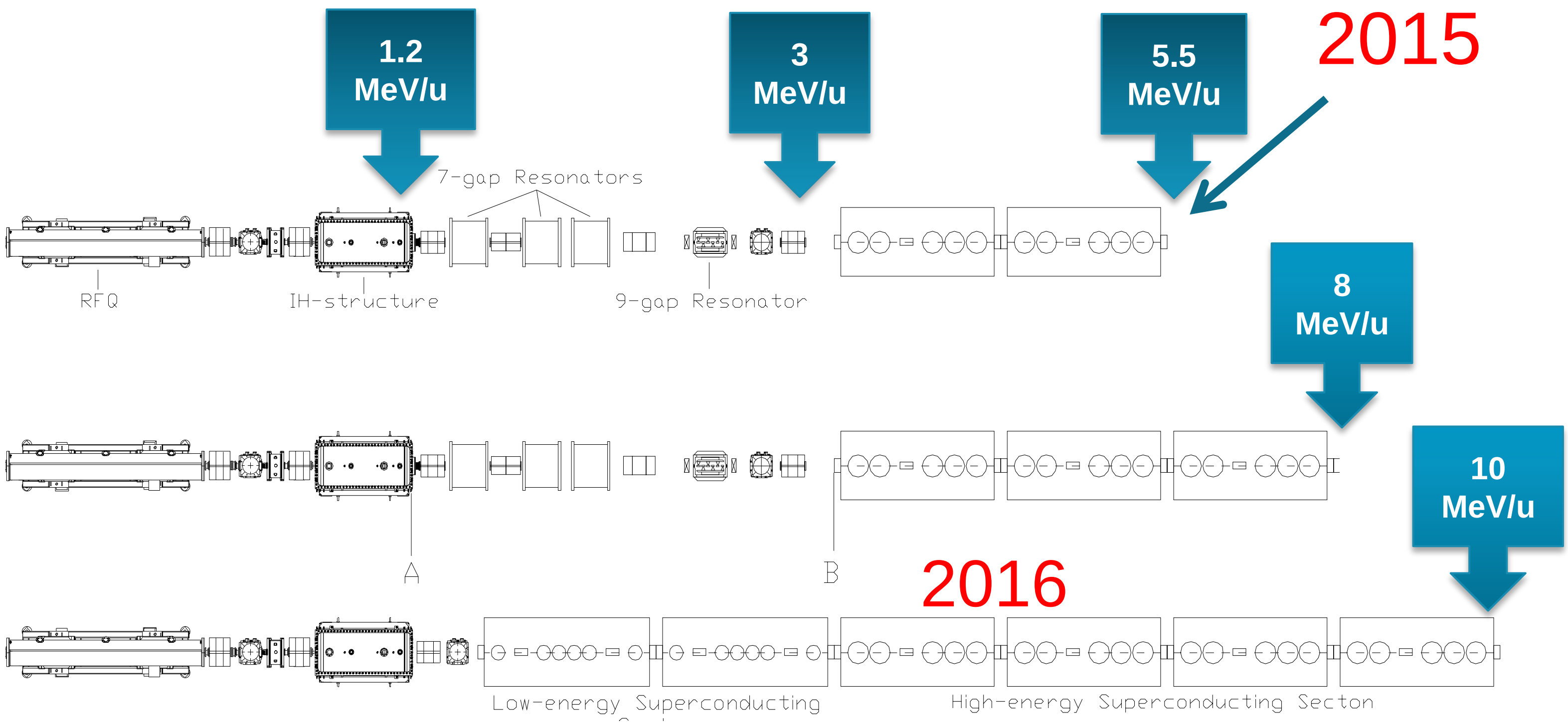
$$\beta^{(s)}(J_k) = \sqrt{\frac{5}{16\pi}} \frac{4\pi}{3ZR^2} \left(-\frac{2J+3}{J}\right) Q_s(J_k)$$



Courtesy of K. Wrzosek-Lipska

HIE-ISOLDE

- **H**igh **I**ntensity and **E**nergy upgrade
- CERN Shutdown = fallow year for ISOLDE experiments
- HIE-ISOLDE upgrade synchronised



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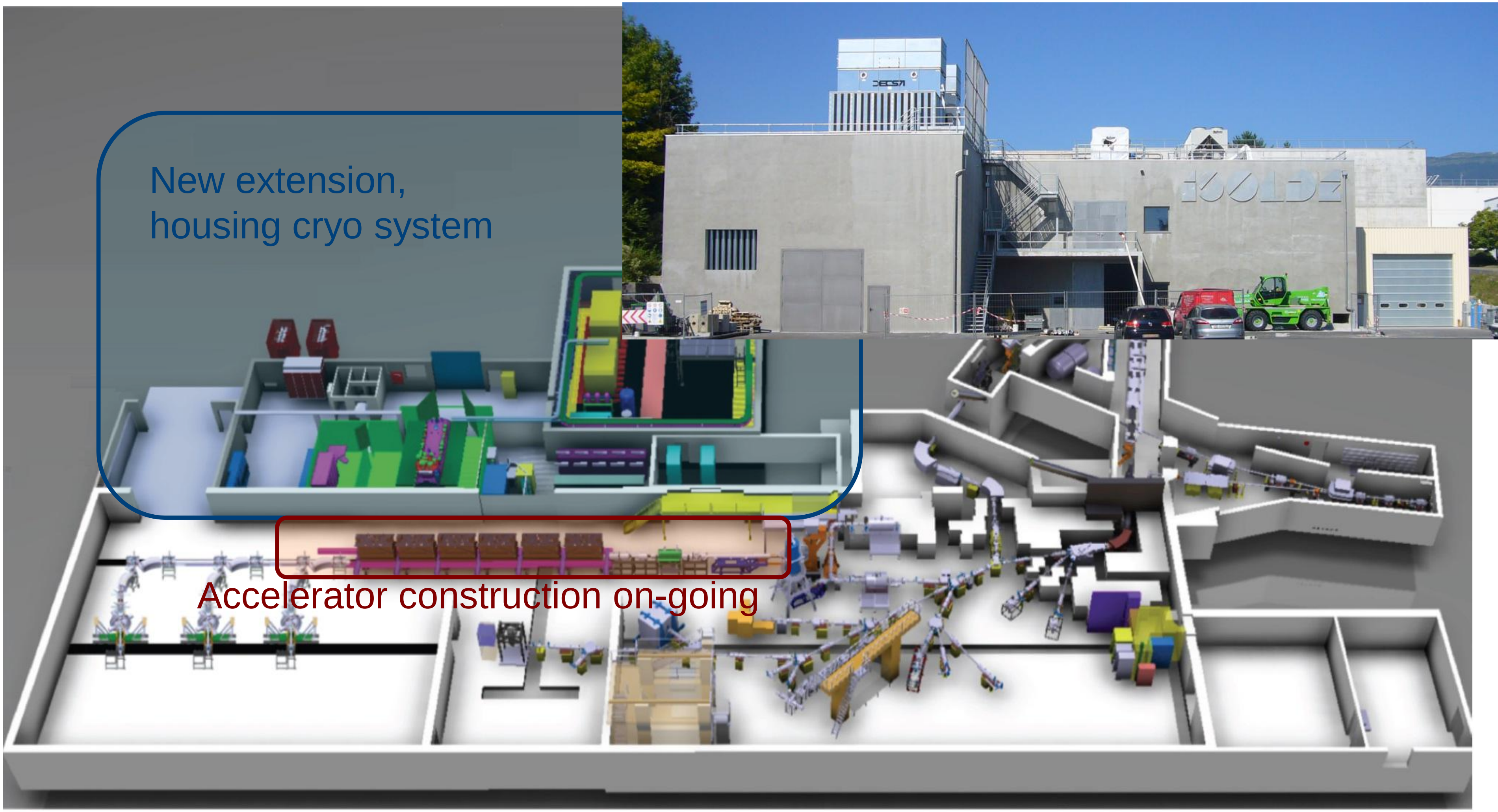
HIE-ISOLDE

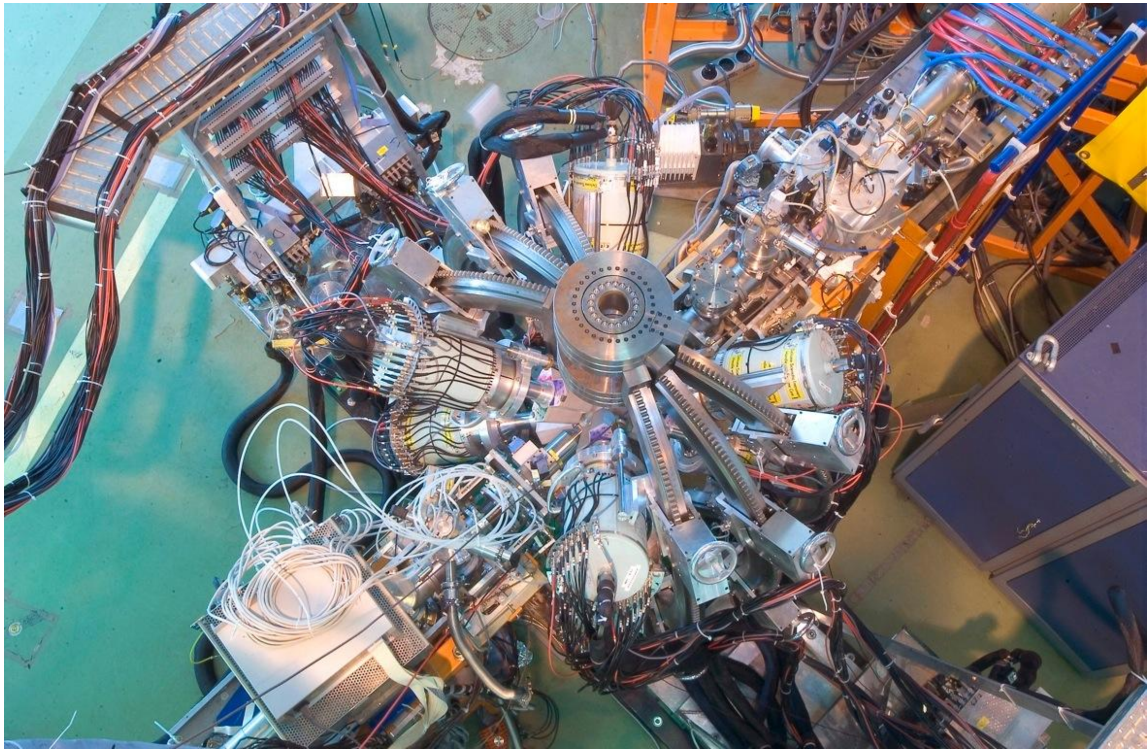

New extension,
housing cryo system
Accelerator construction on-going
ISOLDE

Summary

- Miniball physics case covers nuclei from Berylium up to Radium
- Detector array "on tour" to Munich and Orsay
- Recent physics results presented:
  - Deformation of shape-coexisting shapes in neutron-deficient Hg
  - Characterisation of 0^+ states in ^{68}Ni with 2-neutron transfer
- The next step: HIE-ISOLDE !!
  - Multi-step Coulex around ^{68}Ni → 4-5 MeV/u
    - Higher-lying B(E2), also non-yrast
    - And spectroscopic quadrupole moments, Q_s!
  - Transfer reactions in the Pb region → 10 MeV/u
    - Limited so far to A~80 at current beam energies
    - 5 MeV/u expands this range
    - 10 MeV/u gives angular distribution sensitivity for e.g. 185Hg

Thanks to spokespersons, analysers and contributors to this talk…

- Peter Reiter (Köln)
- Michael Seidlitz (Köln)
- Piet Van Duppen (Leuven)
- Thorsten Kröll (Darmstadt)
- Freddy Flavigny (Leuven)
- Jan Diriken (Leuven)
- Jytte Elseviers (Leuven)
- Nele Kesteloot (Leuven)
- Kasia Wrzosek-Lipska (Leuven)
- Nick Bree (Leuven)
- Tuomas Grahn (Jyväskylä)
- Janne Pakarinen (Jyväskylä)
- Jacob Johansen (Aarhus/Darmstadt)
- Denis Mücher (München)
- Steffi Hellgartner (München)
- Riccardo Orlandi (Leuven/Tokai)
- George O'Neill (Liverpool)
- Steffi Hellgartner (Munich)
- Malin Klintefjord (Oslo)



EGAN
European Gamma and Ancillary detectors Network

BriX

belspo

fwo

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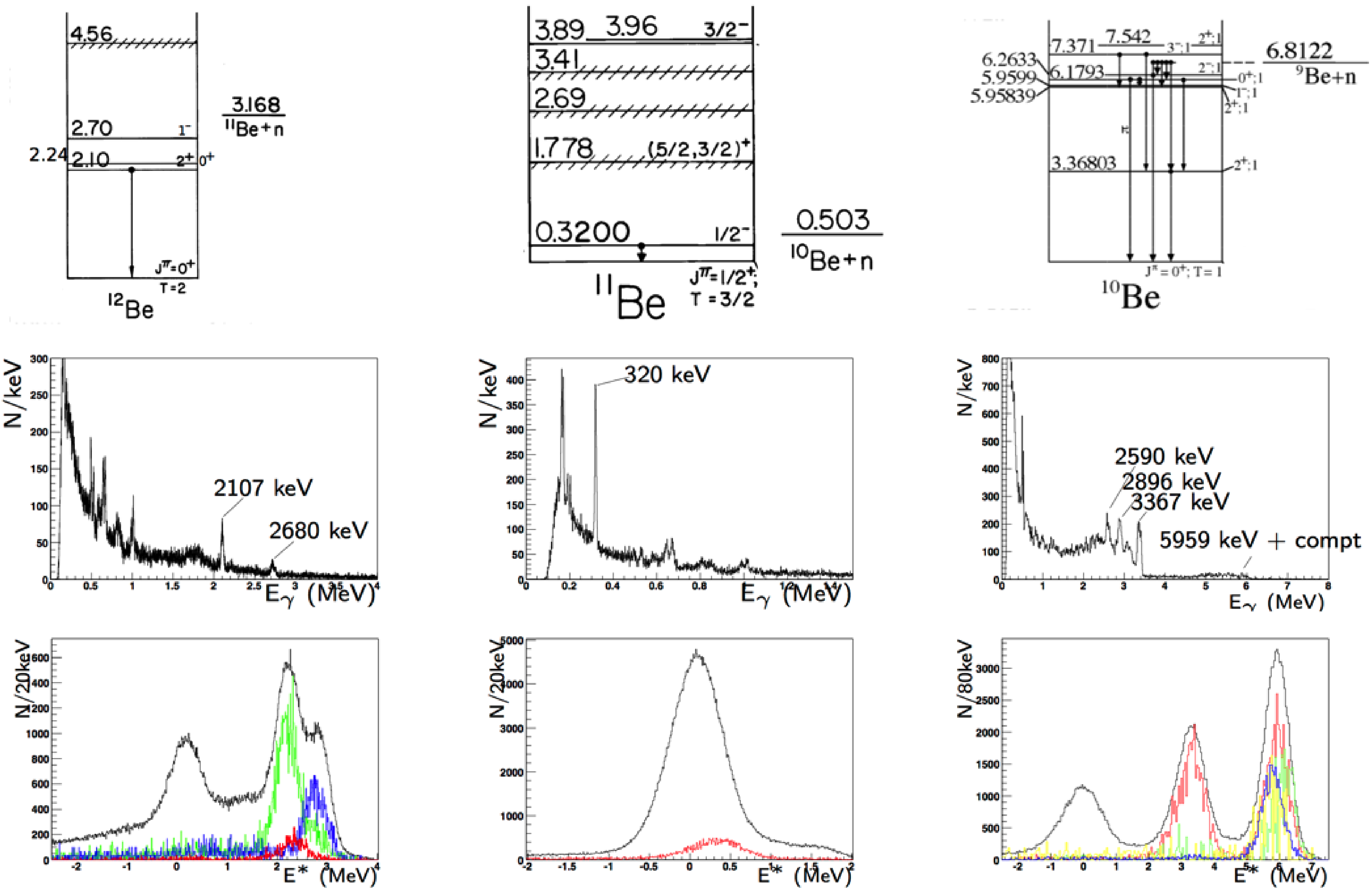
Extra slides

^{11}Be transfer

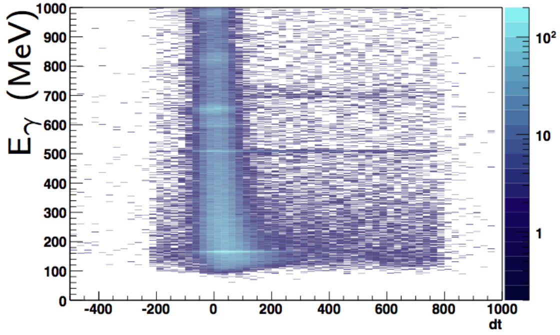
The gamma and excitation energy spectra

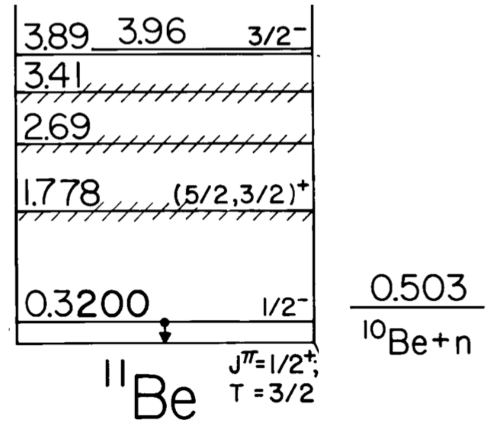


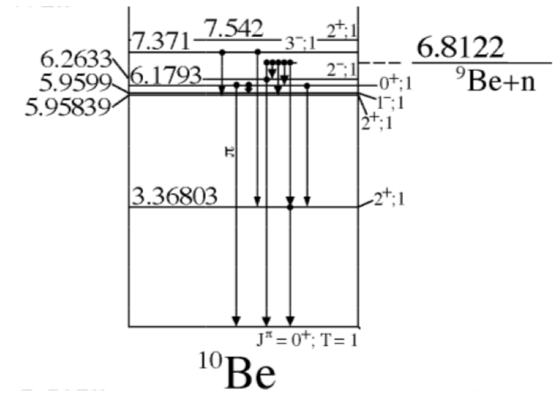
All states except 0_2^+ in ^{10}Be (only weakly populated) are identified.

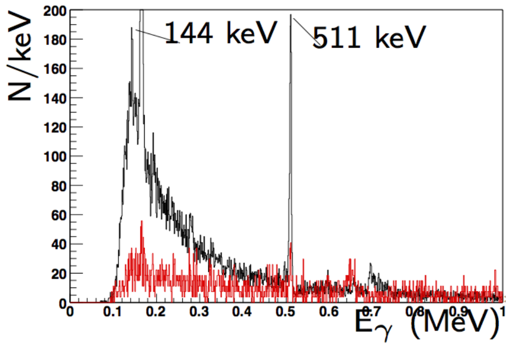
The gamma and excitation energy spectra

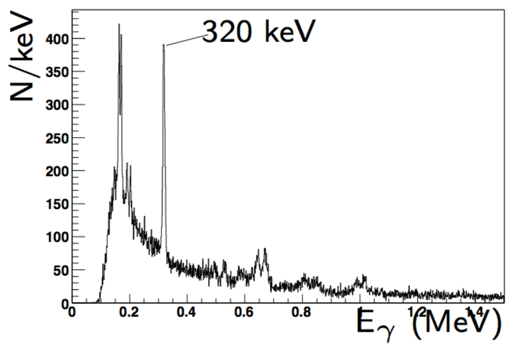
Long lived 0_2^+

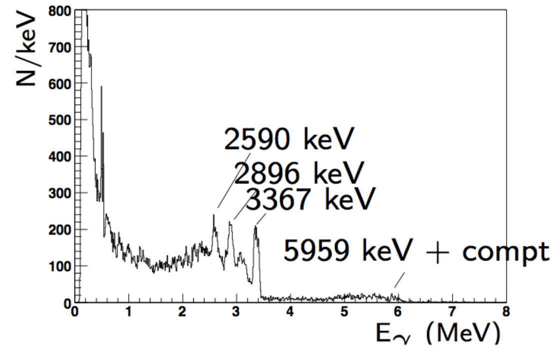


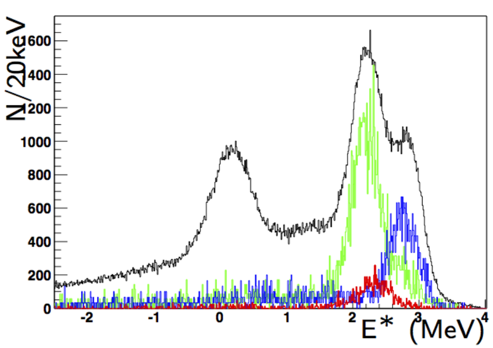


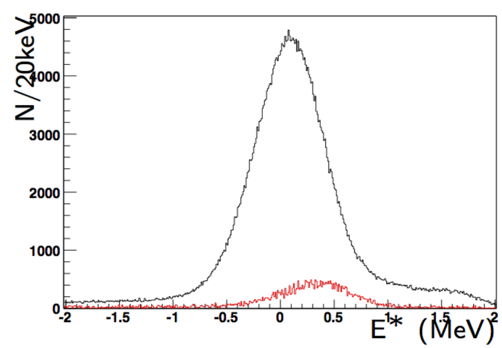


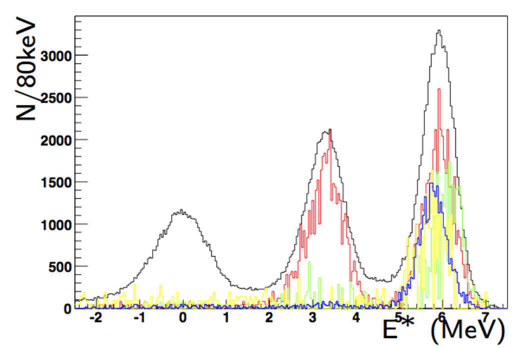






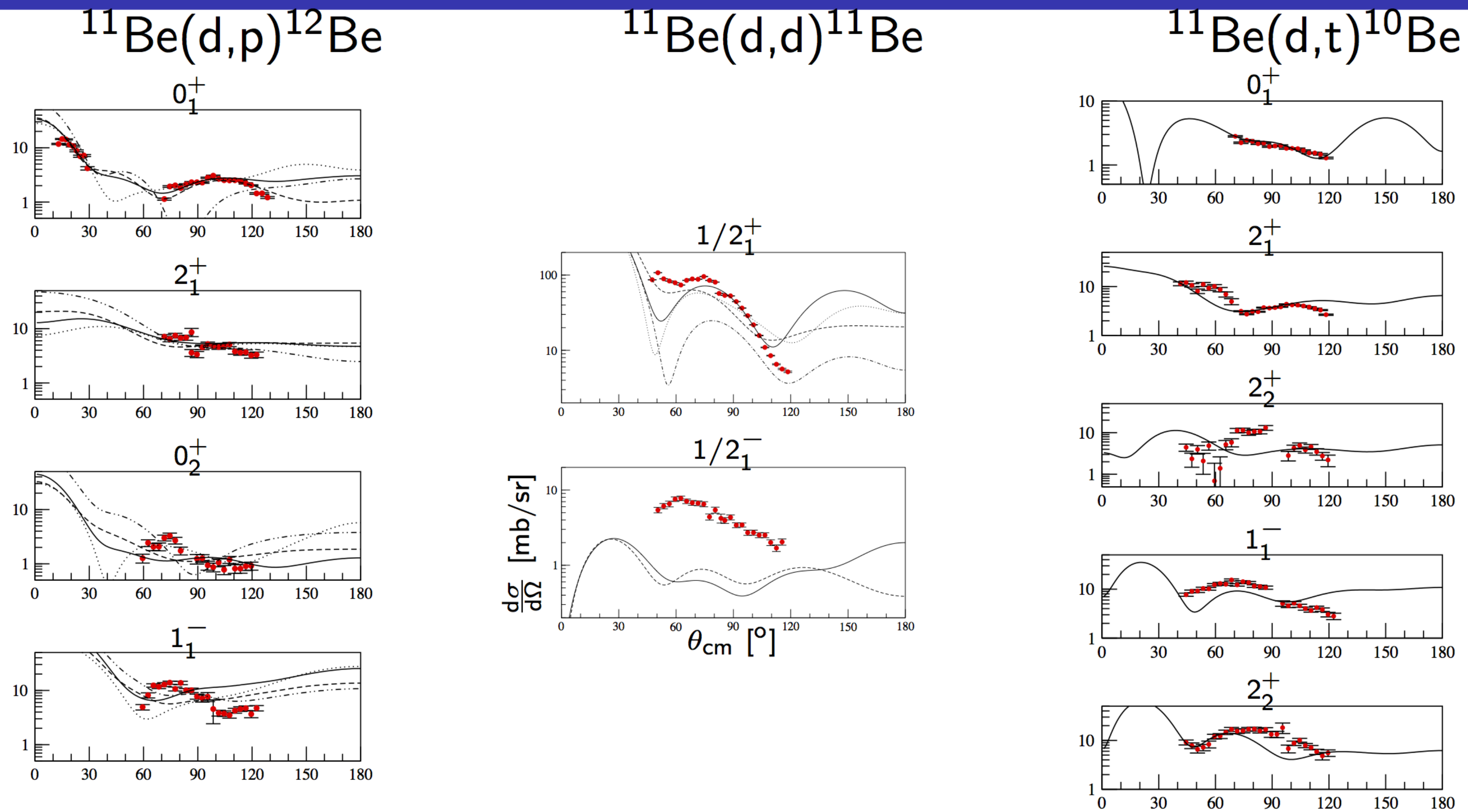






All states except 0_2^+ in ^{10}Be (only weakly populated) are identified.

Differential cross sections



Differential cross sections over a large angular range is determined for all the identified states:

^{12}Be results published: J. G. Johansen et al., PRC 88 044619 (2013)

Extra slides

^{68}Ni transfer

Reaction model

Two-neutron transfer :

Direct pair transfer + Two sequential one-nucleon transfer

Reaction code website :

http://www.nndc.bnl.gov/codes/

Parameters of our FRESCO[1] calculations:

- Finite-range DWBA
- Optical potentials : ^{3}H+^{66}Ni and ^{1}H+^{68}Ni
- Two nucleon overlap amplitudes (TNA's) – contain the structure properties
  - calculated with NUSHELL (A. Brown, MSU) [2]
  - interaction jj44pna from [3]
  - $f_{5/2}$,$p_{3/2}$,$p_{1/2}$,$g_{9/2}$ model space
  - Calculated ^{68}Ni energies (E(0^{+}_{2}) = 1593 kev, E(2^{+}_{1}) = 2077 keV)

[1] www.fresco.org.uk [2] B. A. Brown and W. D. M. Rae, Nushell@MSU 2007 [3] A. F. Lisetskiy et al., PRC 70, 044314 (2004)

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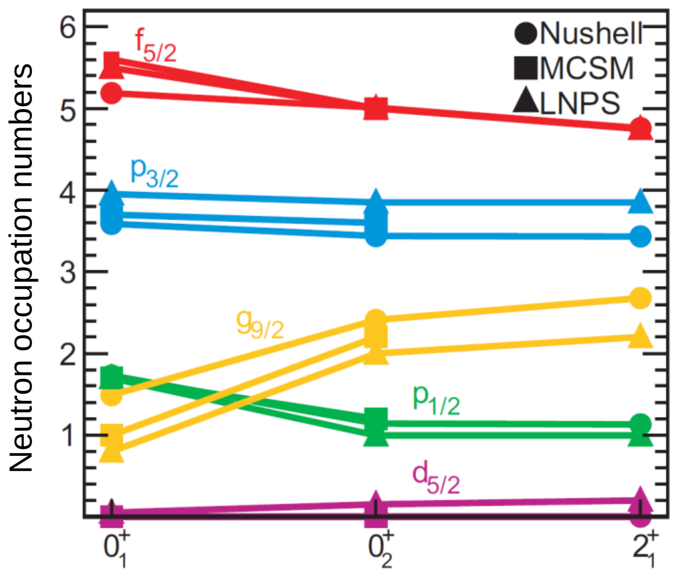
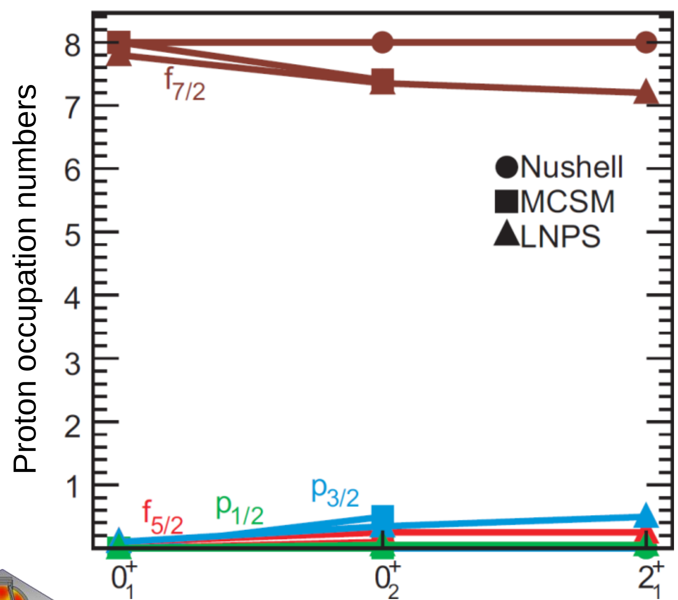
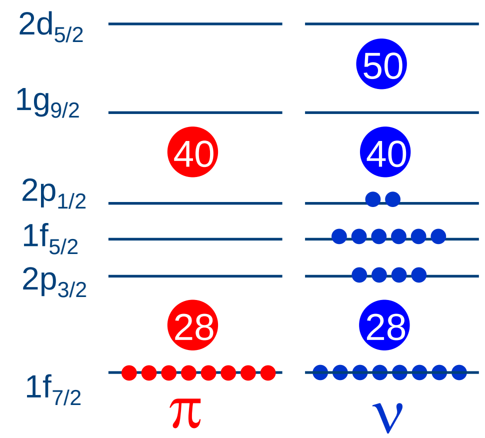
Calculated occupations







Interaction:	jj44pna [1]	LNPS [2]	MCSM [3]
Mod. space (n)	p $f_{5/2}$ g	$pf_{5/2}gd$	pfgd
Mod. space (p)	--	pf	pfgd

Average number of neutrons in a given state

Interaction: jj44pna [1]

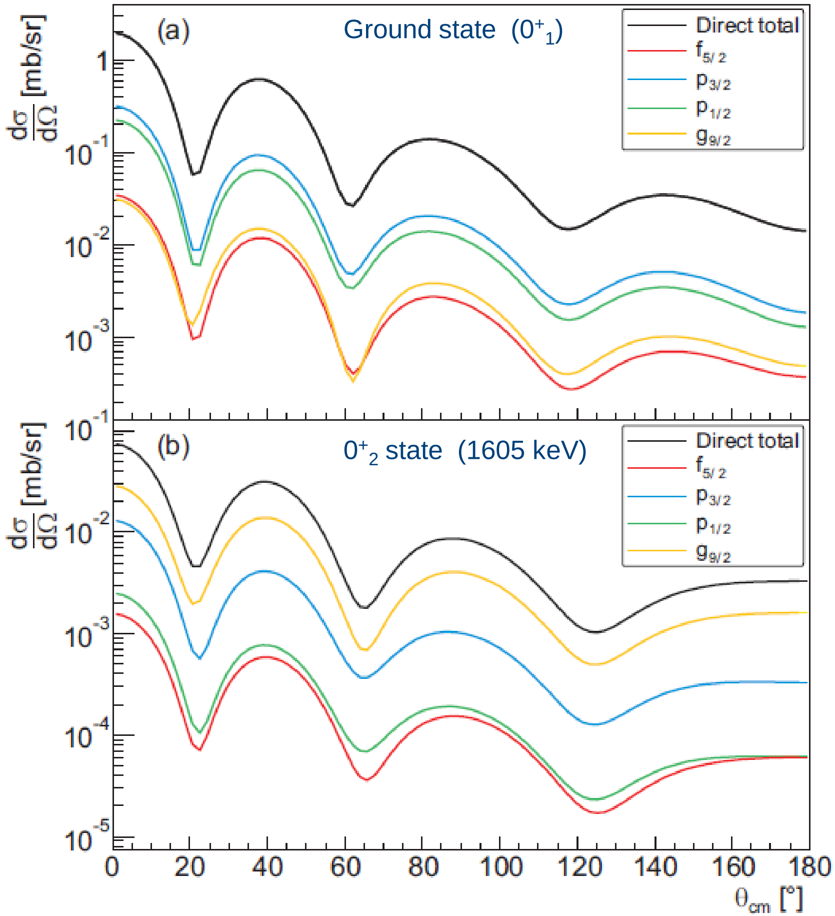
Model space: $f_{5/2},p_{3/2},p_{1/2},g_{9/2}$

	$f_{5/2}$		$p_{3/2}$		$p_{1/2}$		$g_{9/2}$	
^{66}Ni gs	4,53		3,34		1,07		1,06	
^{68}Ni gs	5,19	+0,66	3,59	+0,25	1,73	**+0,66**	1,49	+0,43
^{68}Ni 0^+_2	5,01	+0,48	3,44	+0,10	1,14	+0,07	2,41	**+1,35**

[1] A. F. Lisetskiy et al., PRC 70, 044314 (2004)
[2] S. Lenzi et al., PRC82 054301 (2010)
[3] Y. Tsunoda et al., PRC89 031301R (2014)

$^{66}Ni(^3H,p)^{68}Ni$: Angular distributions

Direct transfer only



Transfer to gs dominated by $(p)^2$ configurations

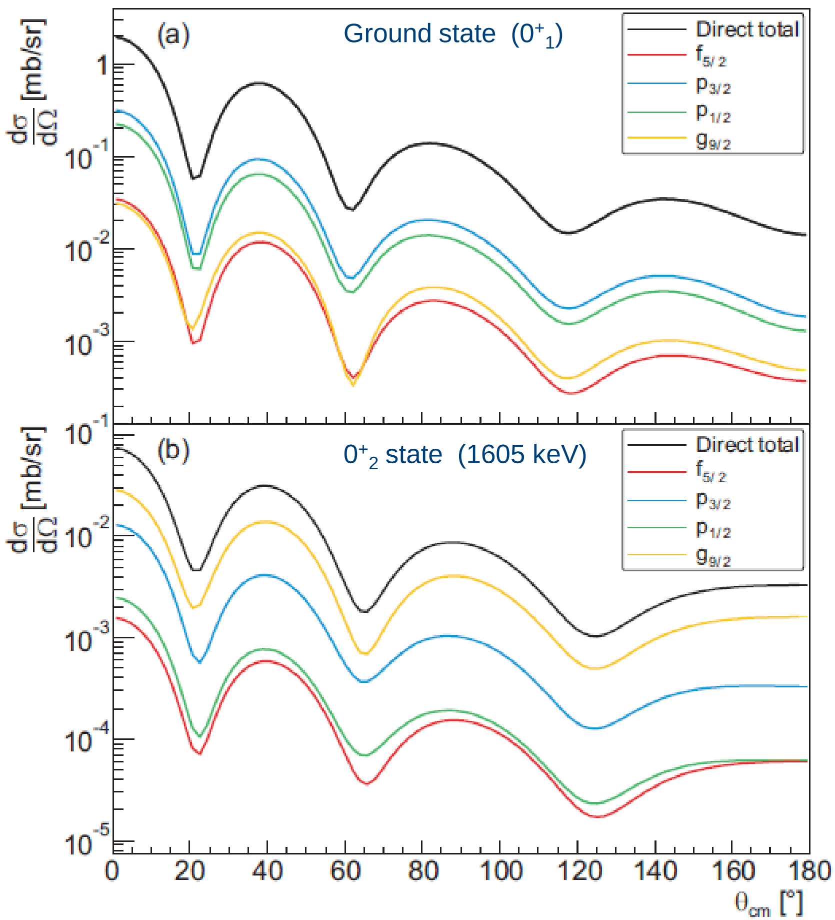
Content of wf with $g_{9/2}$ empty: 42%

Transfer to 0^+_2 dominated by $(g_{9/2})^2$ configurations

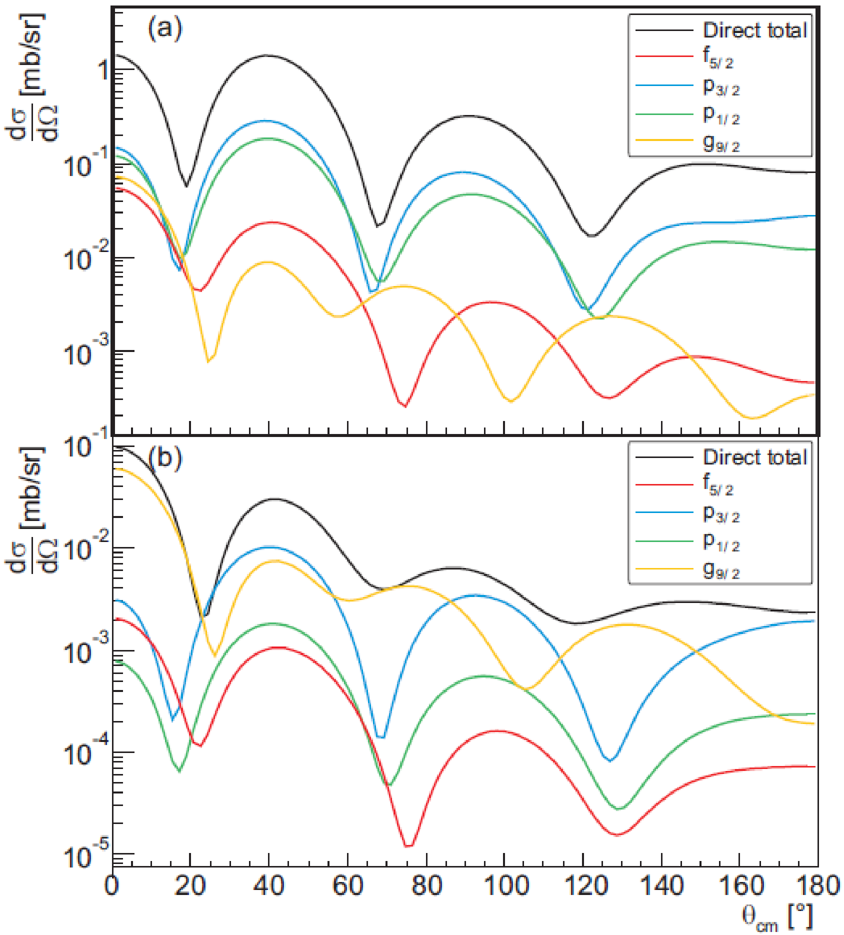
Content of wf with $g_{9/2}$ empty: 14%

^{66}Ni(^{3}H,p)^{68}Ni : Angular distributions

Direct transfer only

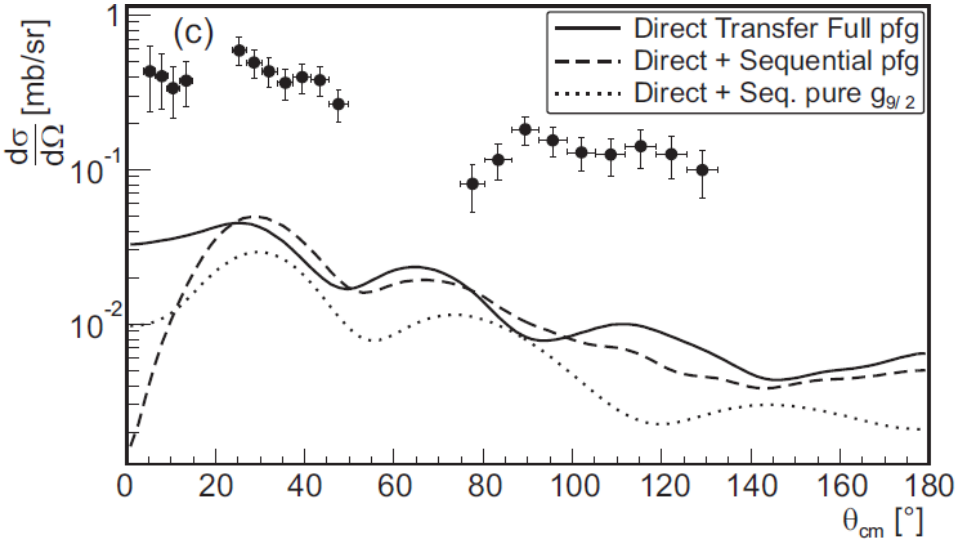


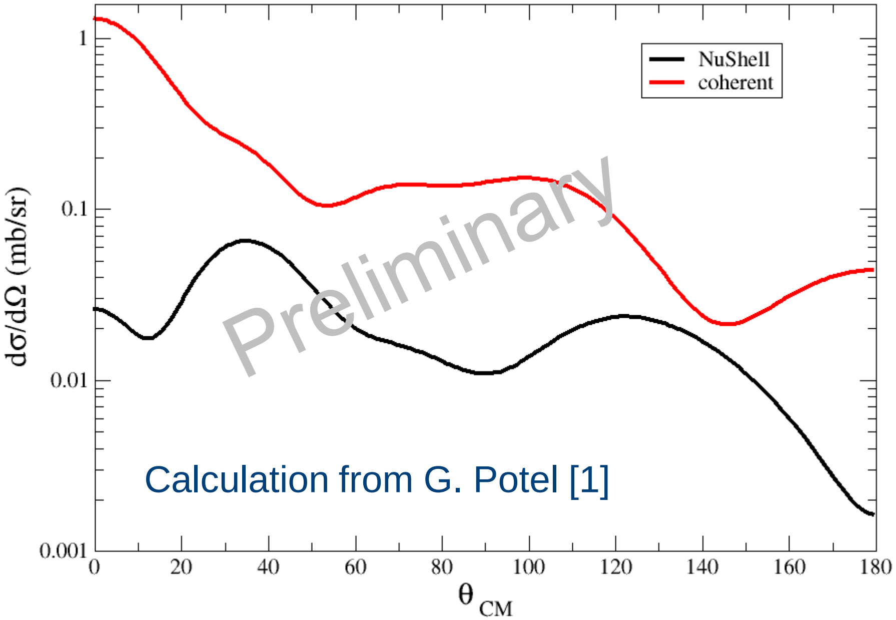
Direct + sequential



Significant effect of sequential transfer → Shape changes

$^{66}Ni(^{3}H,p)^{68}Ni$: Angular distributions





Conclusions:

- First calculation far too low
- Work in progress
- Phase conventions are crucial

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Extra slides

^{123}Cd Coulex

Neutron-rich Cd isotopes

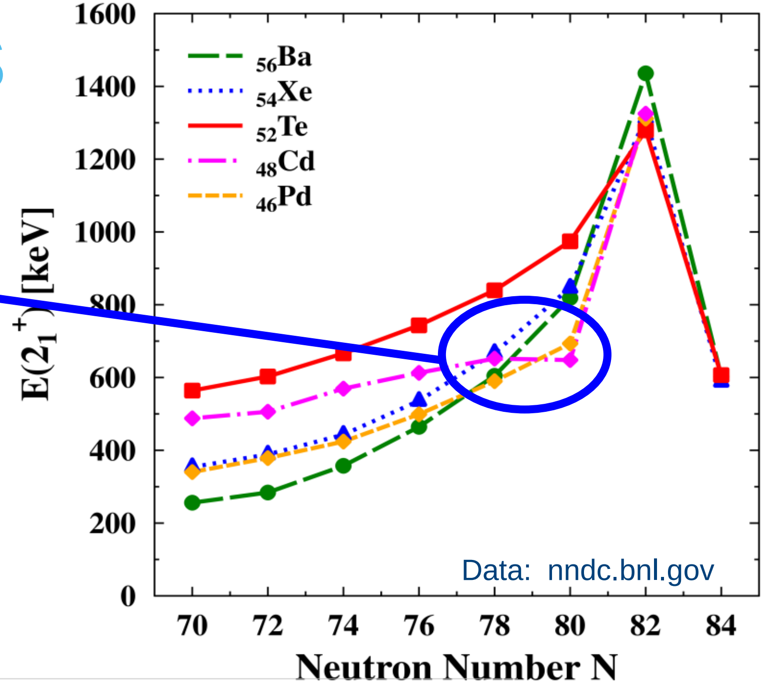
- Coulomb excitation indeed confirms 646 keV to be $2^+ \rightarrow 0^+$ transition
- ^{128}In contamination also excited

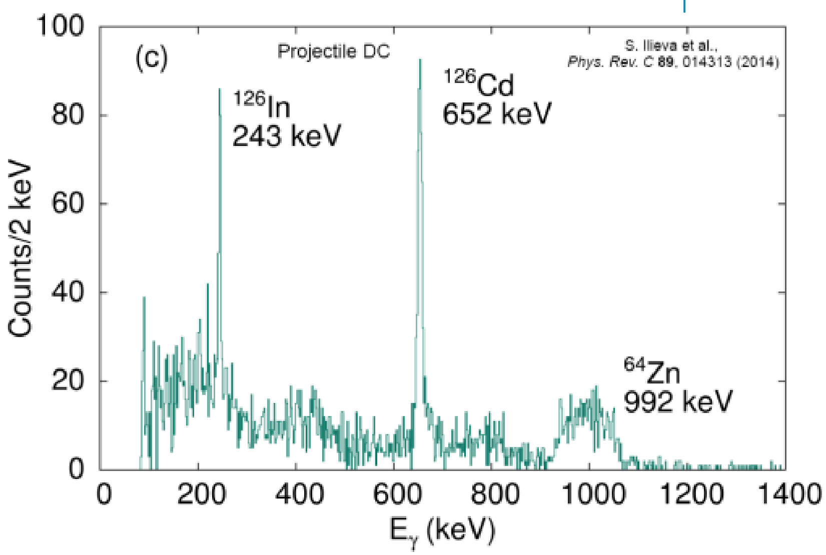
Data segmented into angular ranges to extract B(E2) and Q_s

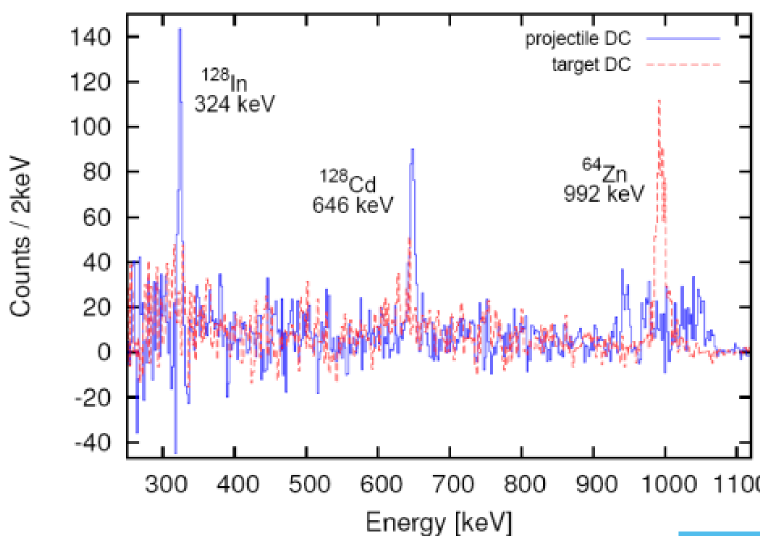
E(2^+) drops from ^{126}Cd to ^{128}Cd!

Not reproduced by SM

Is ^{128}Cd prolate deformed!?!







TECHNISCHE UNIVERSITÄT DARMSTADT

Analysis of ^{128}Cd/^{128}In: Sabine Bönig (PhD thesis, TU Darmstadt, 2014)

W. Watanabe et al., PRL 111, 152501 (2013)
T. R. Rodríguez et al., Phys. Lett. B668, 410 (2008)

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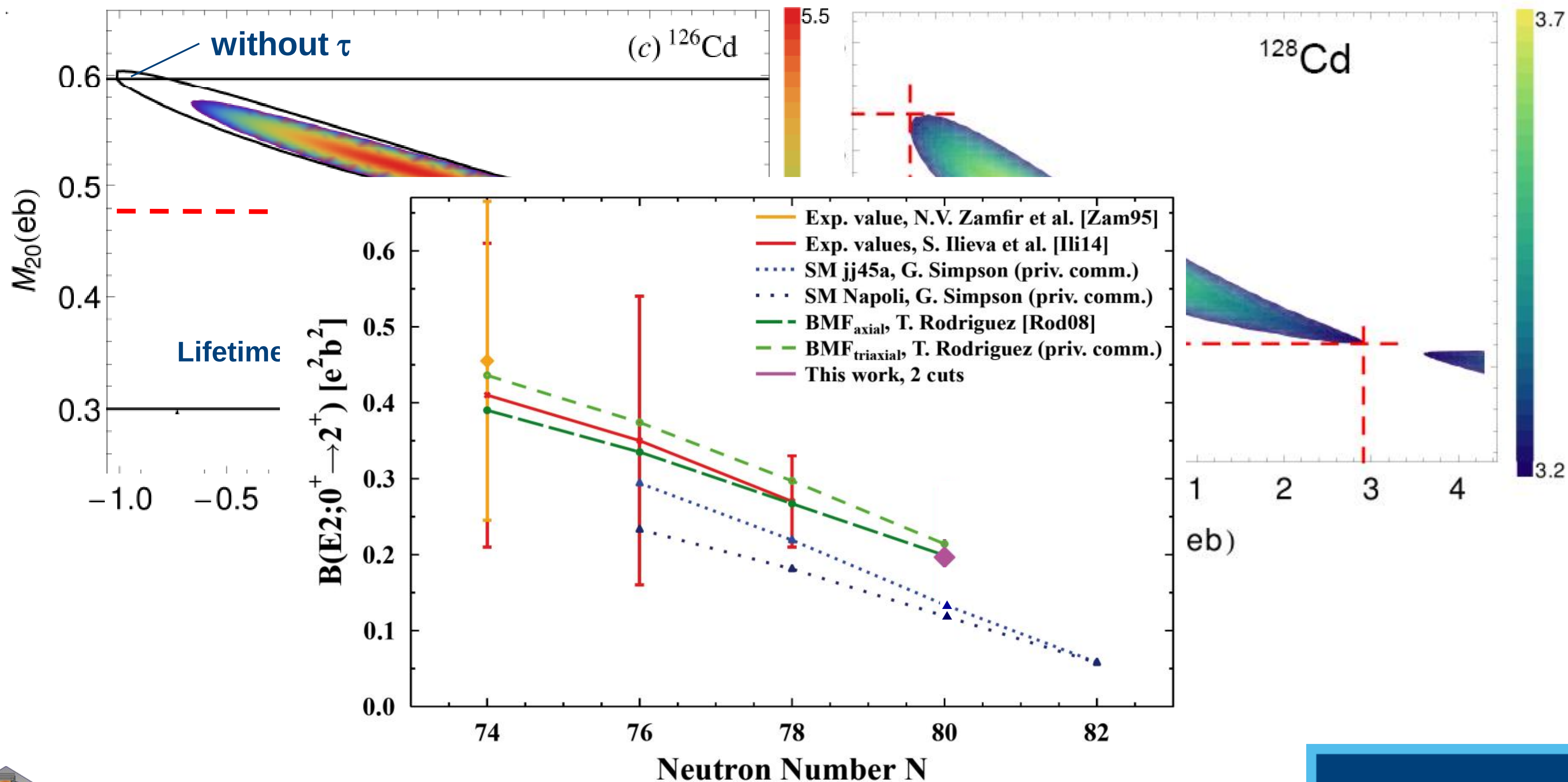
Maximum likelihood fit – $^{126,128}Cd$

- find optimal M_{20}-M_{22} combination
- if available, additional information like lifetimes is included
- projection of 1σ contour on axes

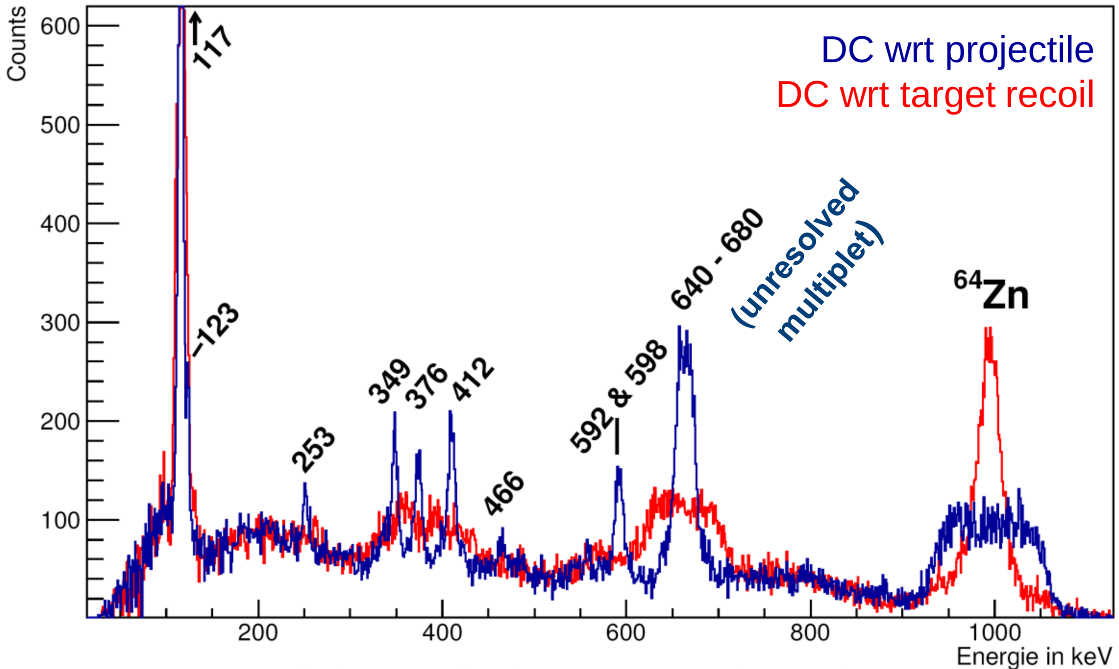
- limited sensitivity to M_{22} (Q_s)
- M_{20} (B(E2)) stable under analysis conditions



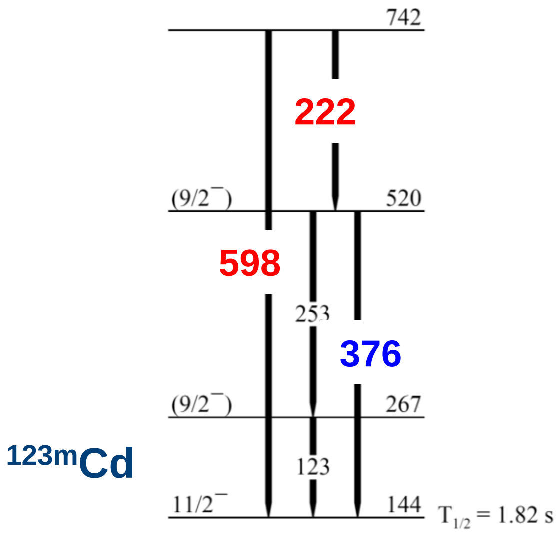
*Michael Thürauf (Master thesis, TU Darmstadt)

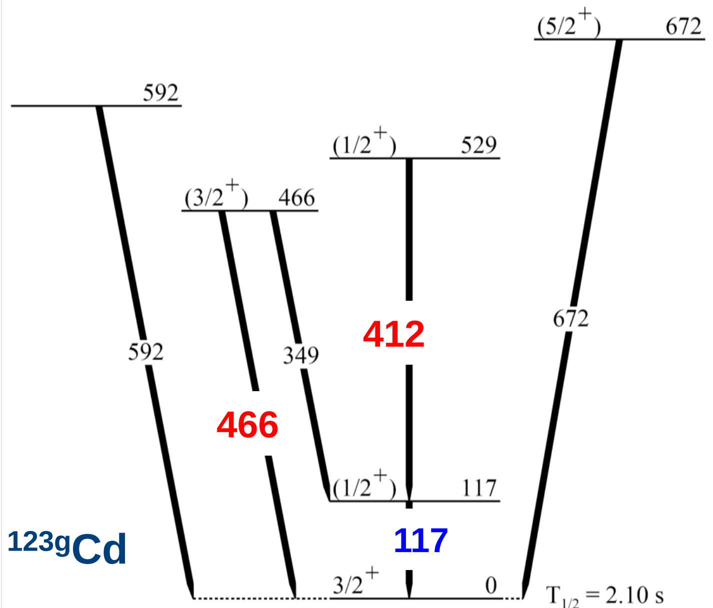
^{123}Cd – first odd Cd isotope

- Coulomb excitation of both ^{123}Cd and ^{123m}Cd
- Level scheme of ^{123}Cd well known in literature ...???



Anna-Lena Hartig (Master thesis, TU Darmstadt, 2014)



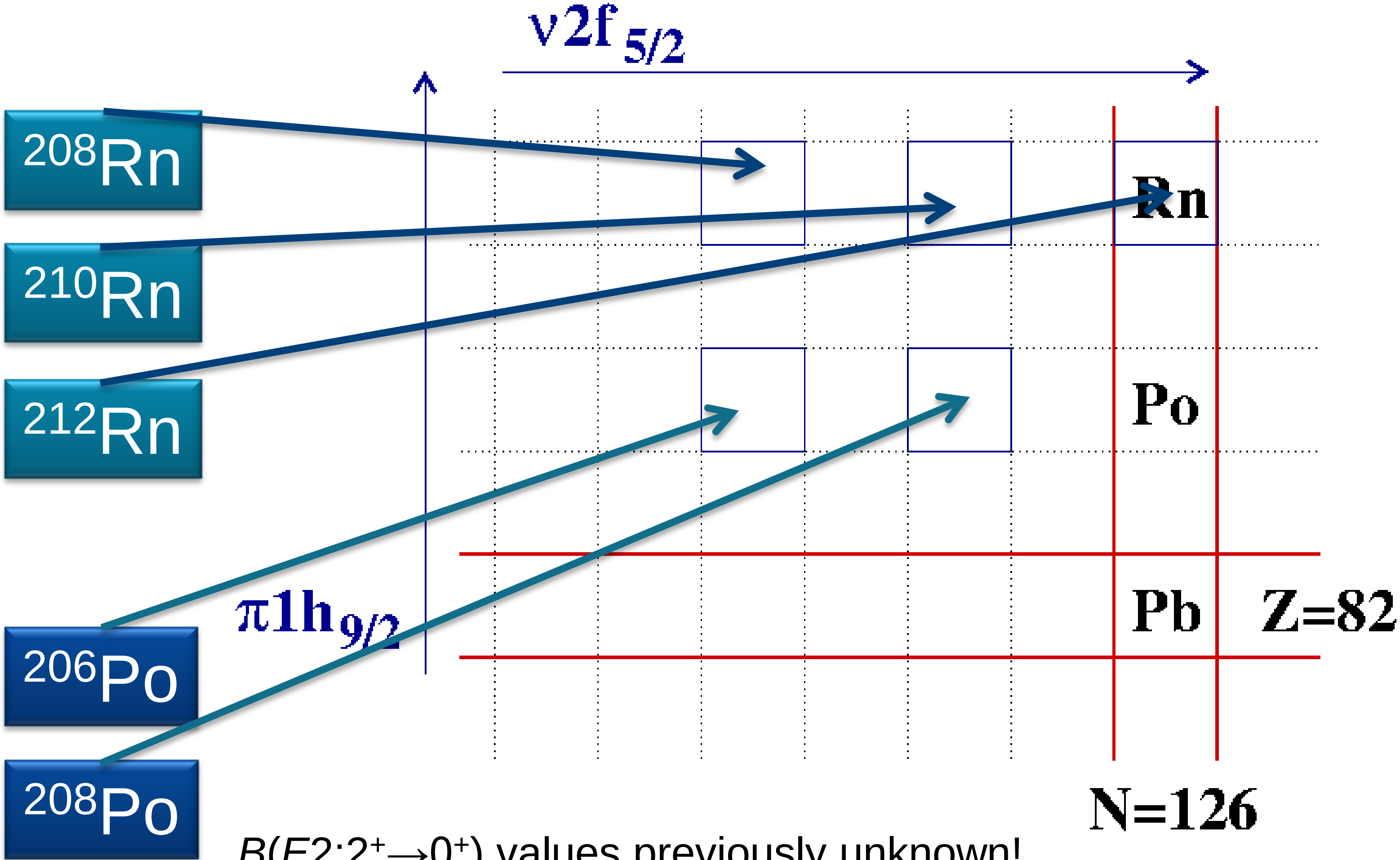


- Mainly single-step excitation
- Very few γ-γ coincidences
- Revisions to level scheme requied

Extra slides

^{208}Rn Coulex

Neutron-deficient trans-Pb region



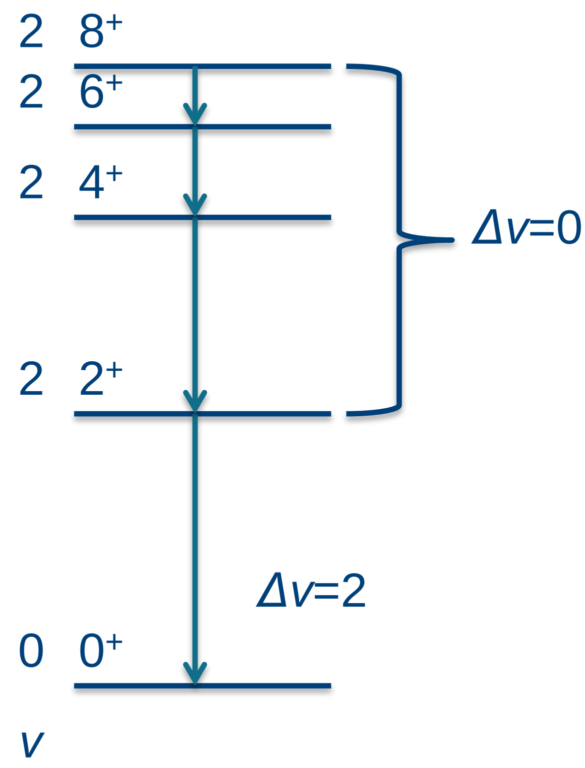
$B(E2;2^+ \rightarrow 0^+)$ values previously unknown!

Neutron-deficient trans-Pb region

Relative high-j proton single-particle orbital (j=9/2) dominates the structure - seniority ν can be regarded as a good quantum number.

In the trans-Pb nuclei with $120 \leq N \leq 128$ the neutrons occupy high n, low ℓ orbitals and therefore they should have weaker interactions with the $1h_{9/2}$ protons. This implies that the seniority can be preserved.

Motivation: **to map the boundaries of seniority regime and collectivity**



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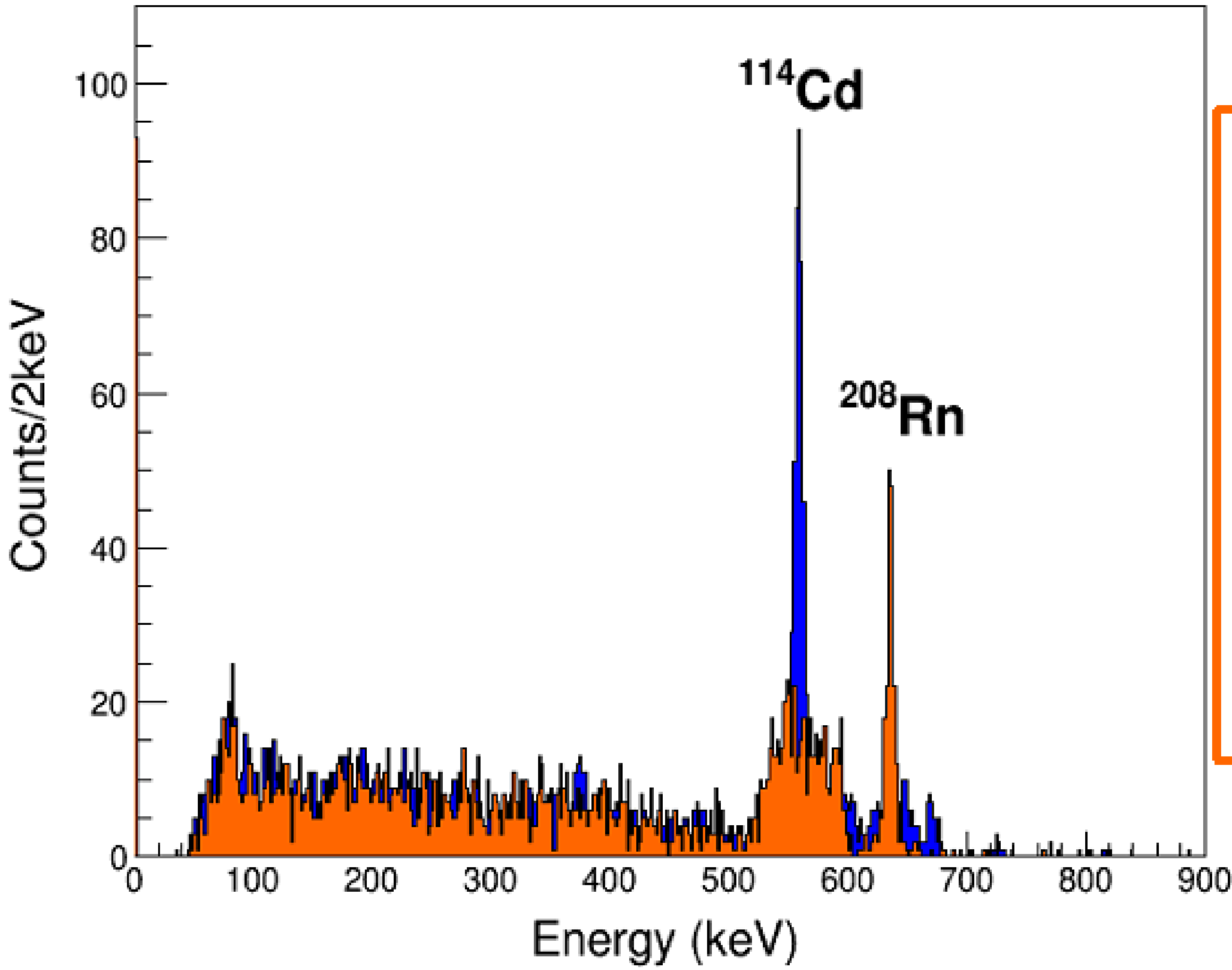

Two-particle gated γ-ray spectrum Doppler corrected for the projectile and target nuclei

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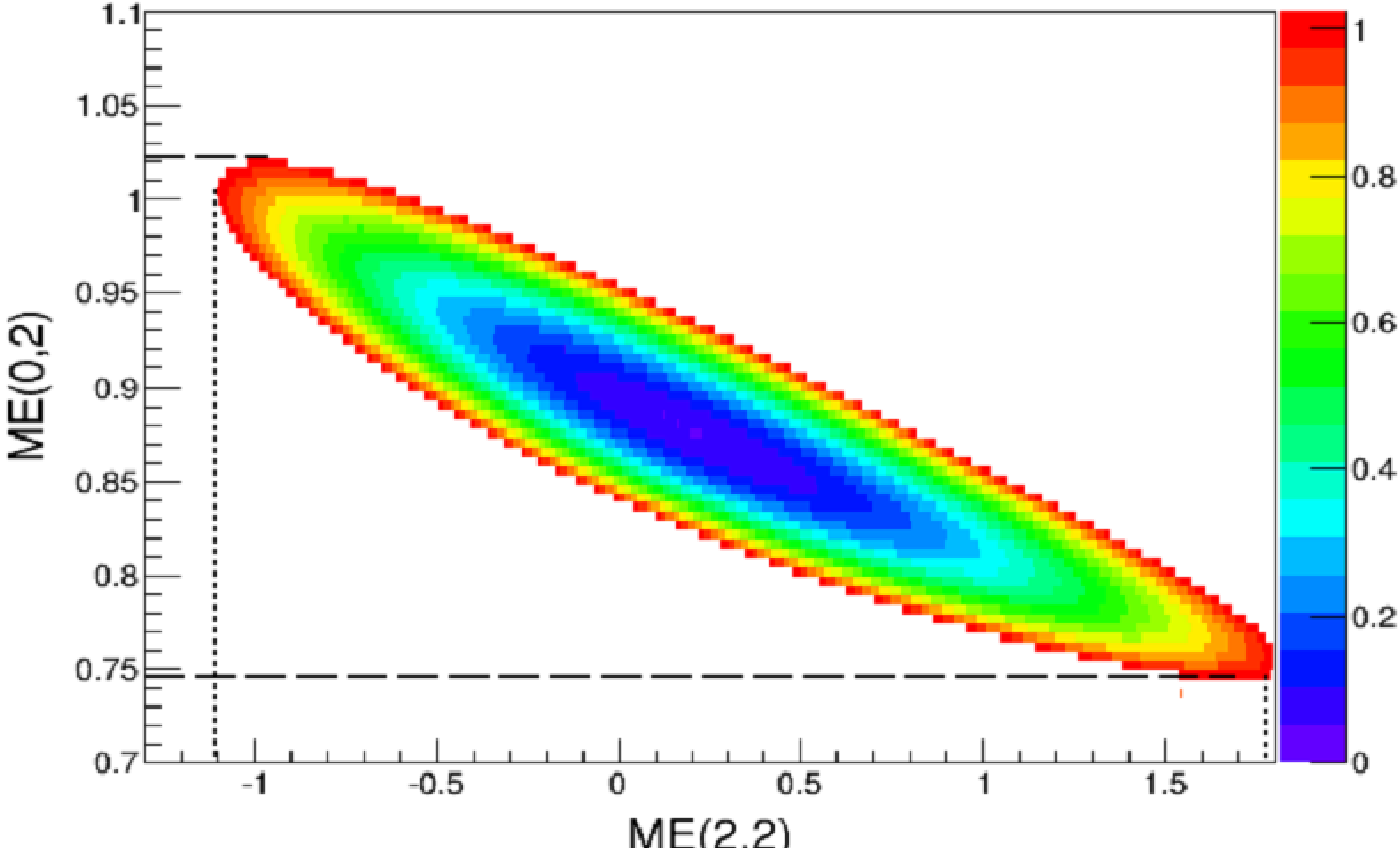


χ^2 +1 surface resulting from the GOSIA2 minimization procedure as a function for the diagonal (ME(2,2)) and transitional (ME(0,2)) matrix elements of the 2^+ state in ^{208}Rn

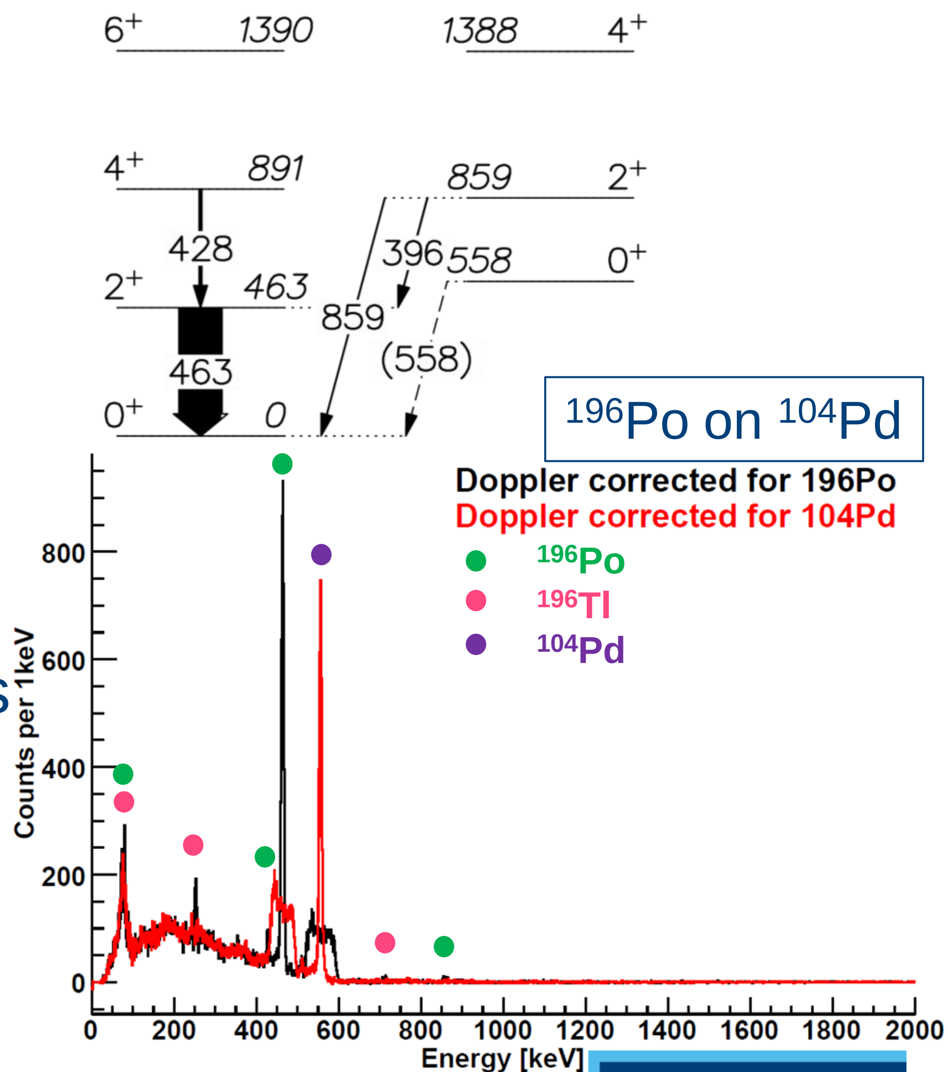
Extra slides

$^{198-202}$Po Coulex

Z = 84: $^{196-202}$Po: Quality of the data

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

- Extraction of matrix elements
  - Gosia
  - χ^2 fit of experimental data

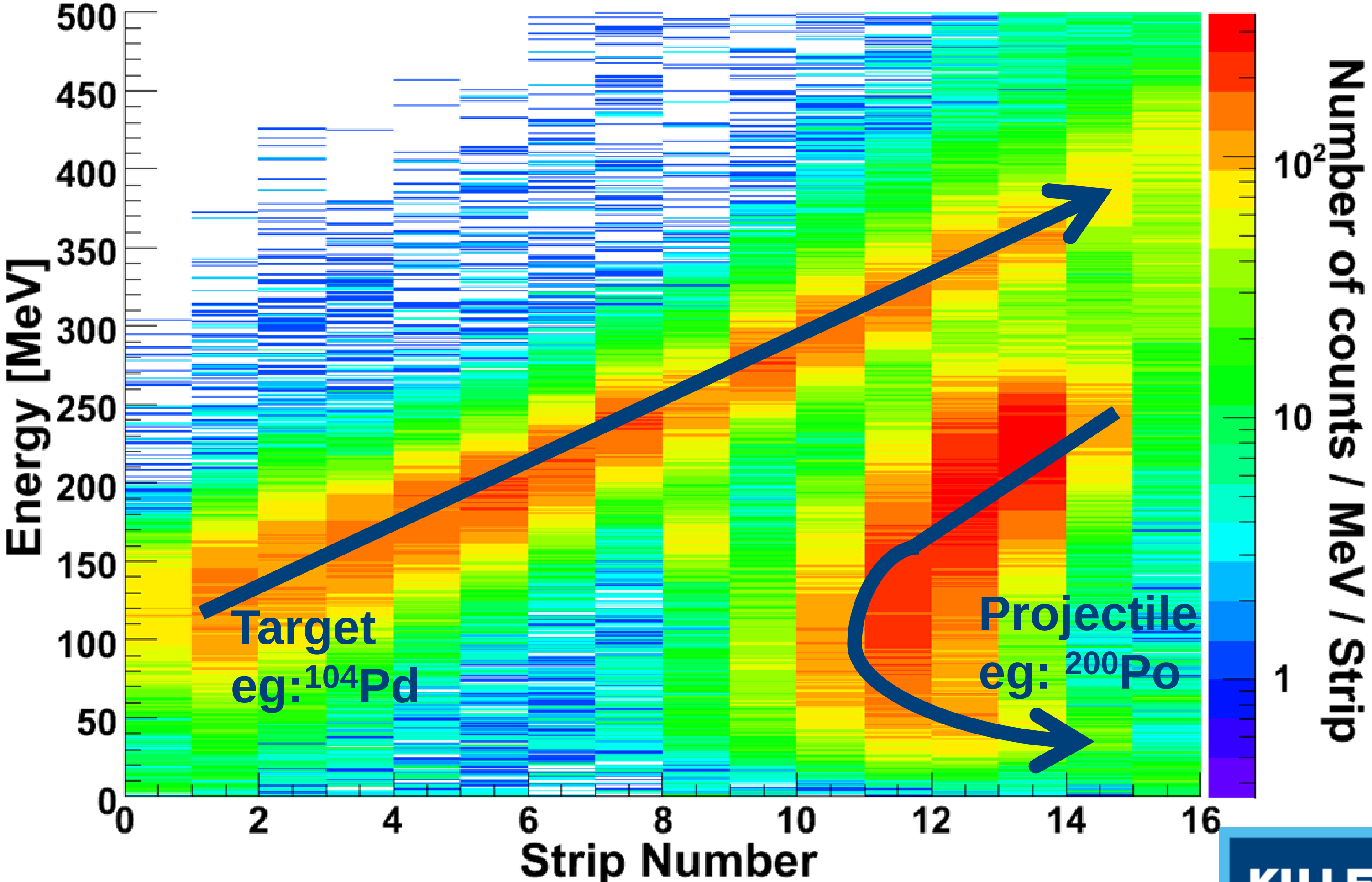


T. Czosnyka et al, Am. Phys. Soc. (1982)

ARIS 2014, Tokyo 50

Z = 84: $^{196-202}$Po: Kinematics

Demand particle particle gamma coincidences
→ Separate projectile and target



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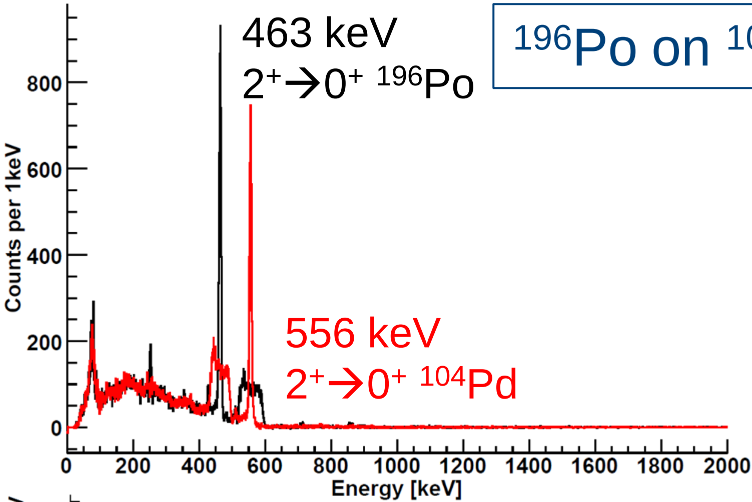
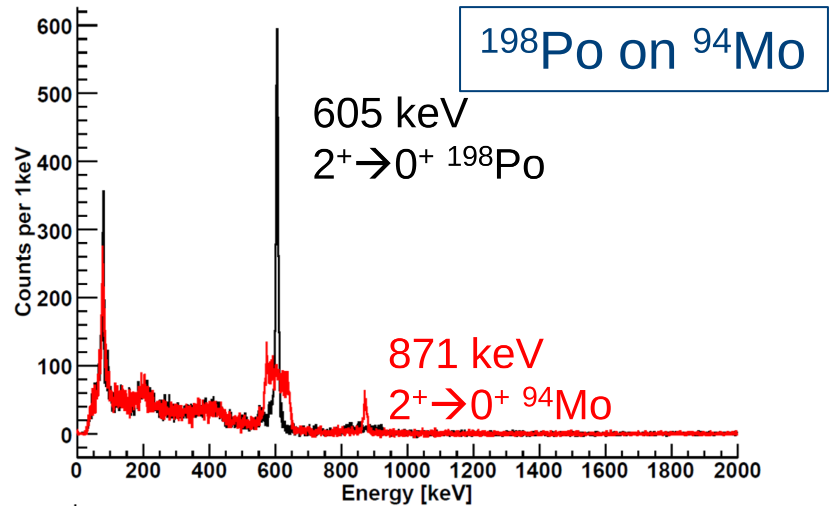
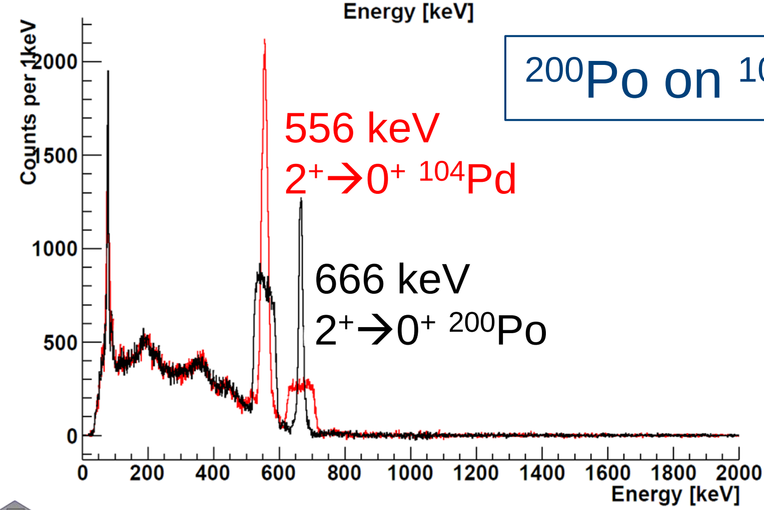
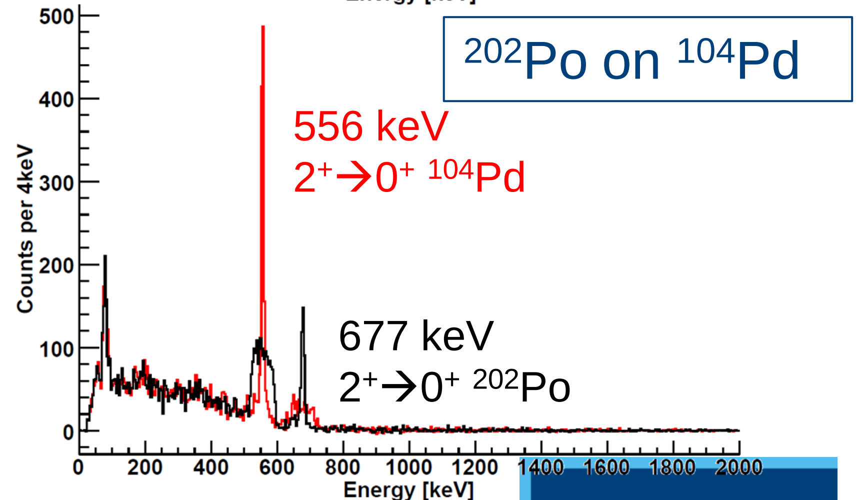
Z = 84: $^{196-202}$Po: γ spectra

pγ + ppγ events, Doppler corrected for projectile/target



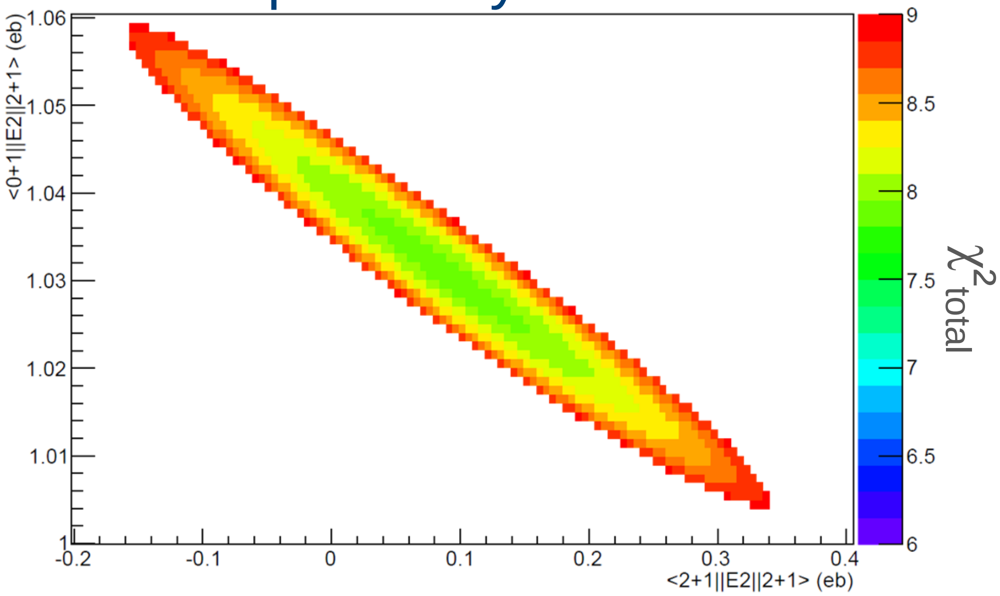






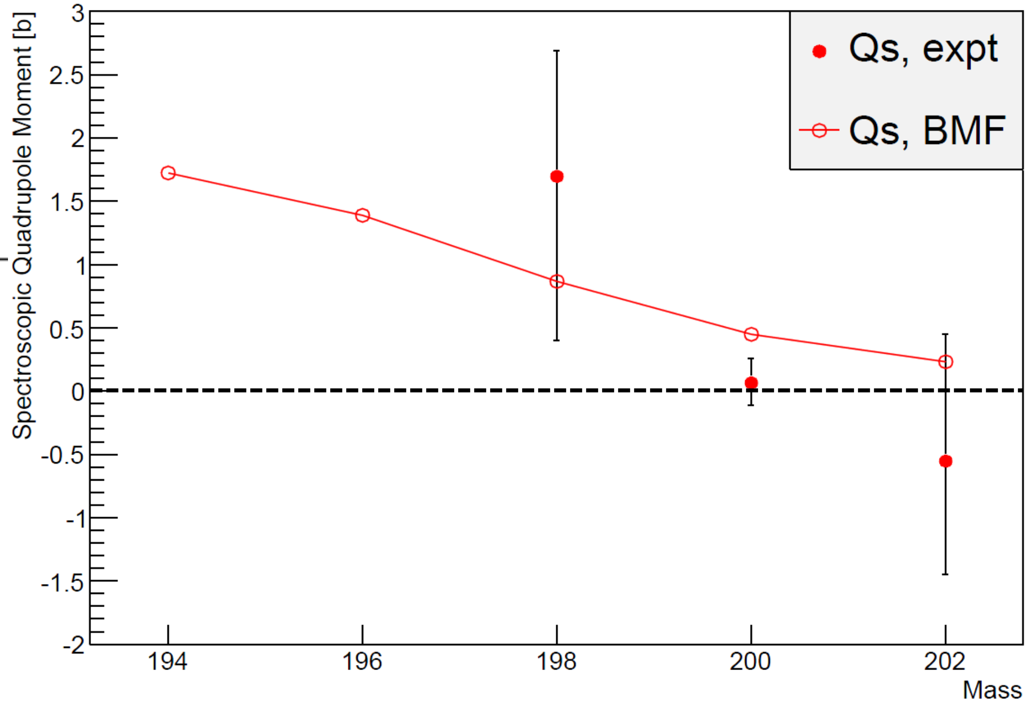
Extracting matrix elements

- Only 2^+_1 state is populated
  - Extract $\langle 0^+_1||E2||2^+_1\rangle$ and $\langle 2^+_1||E2||2^+_1\rangle$
  - χ^2 surface to look for best solution
  - Example: ^{200}Po on ^{104}Pd
- Multi-step coulex observed
  - First step in analysis



χ^2min = 7.9
$\langle 0^+_1||E2||2^+_1\rangle$ = 1.03(3) eb
$\langle 2^+_1||E2||2^+_1\rangle$ = 0.1(2) eb

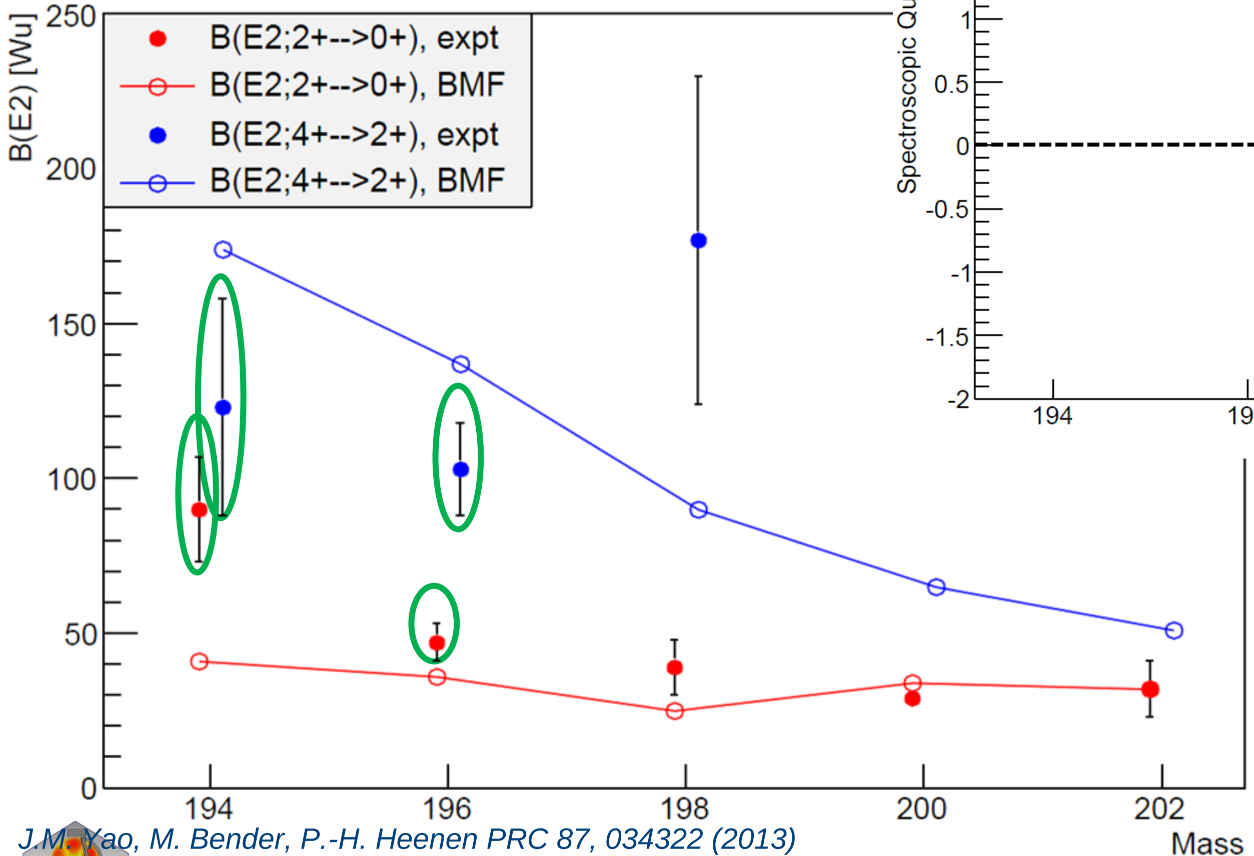
Comparison with Beyond Mean Field



Lifetime experiments

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

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

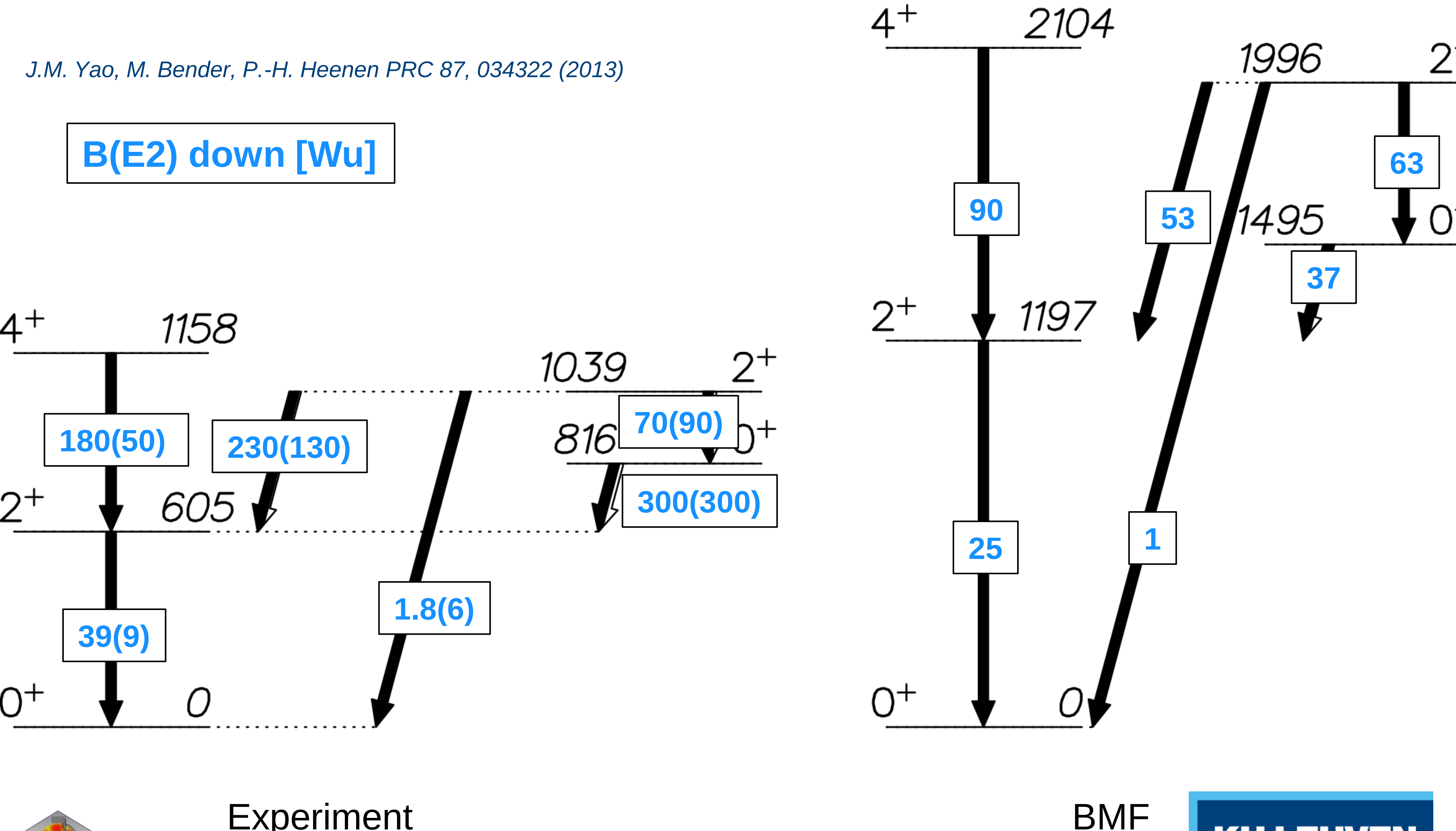


J.M. Yao, M. Bender, P.-H. Heenen PRC 87, 034322 (2013)

Comparison with Beyond Mean Field: ^{198}Po

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

B(E2) down [Wu]

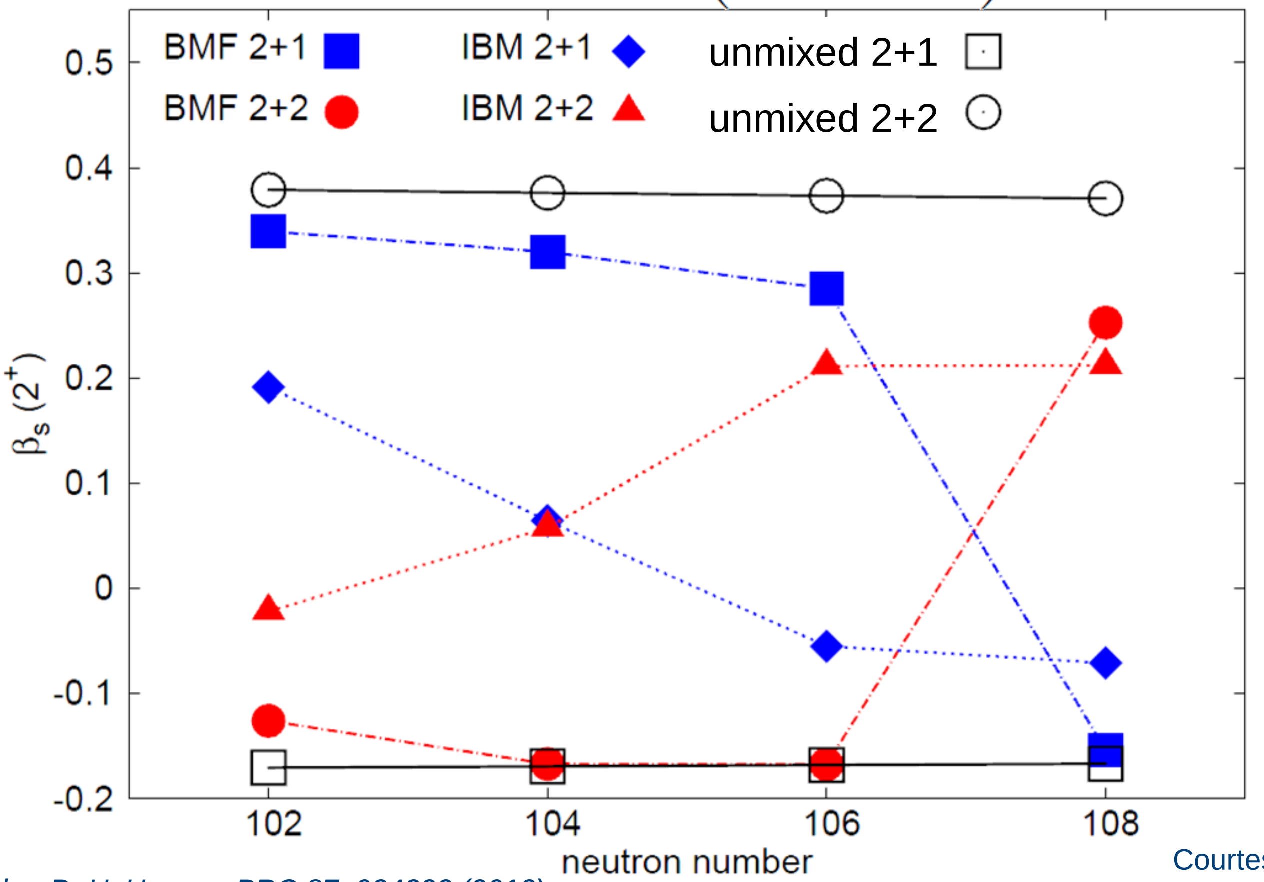


Extra slides

$^{182-188}$Hg Coulex

Comparison to theory – IBM and BMF

$$\beta^{(s)}(J_k) = \sqrt{\frac{5}{16\pi}\frac{4\pi}{3ZR^2}}\left(-\frac{2J+3}{J}\right)Q_s(J_k)$$



Courtesy of K. Wrzosek-Lipska

BMF: J.M. Yao, M. Bender, P.-H. Heenen PRC 87, 034322 (2013)
IBM: J.E. Garcia-Ramos, K. Heyde PRC 89, 014306 (2014)

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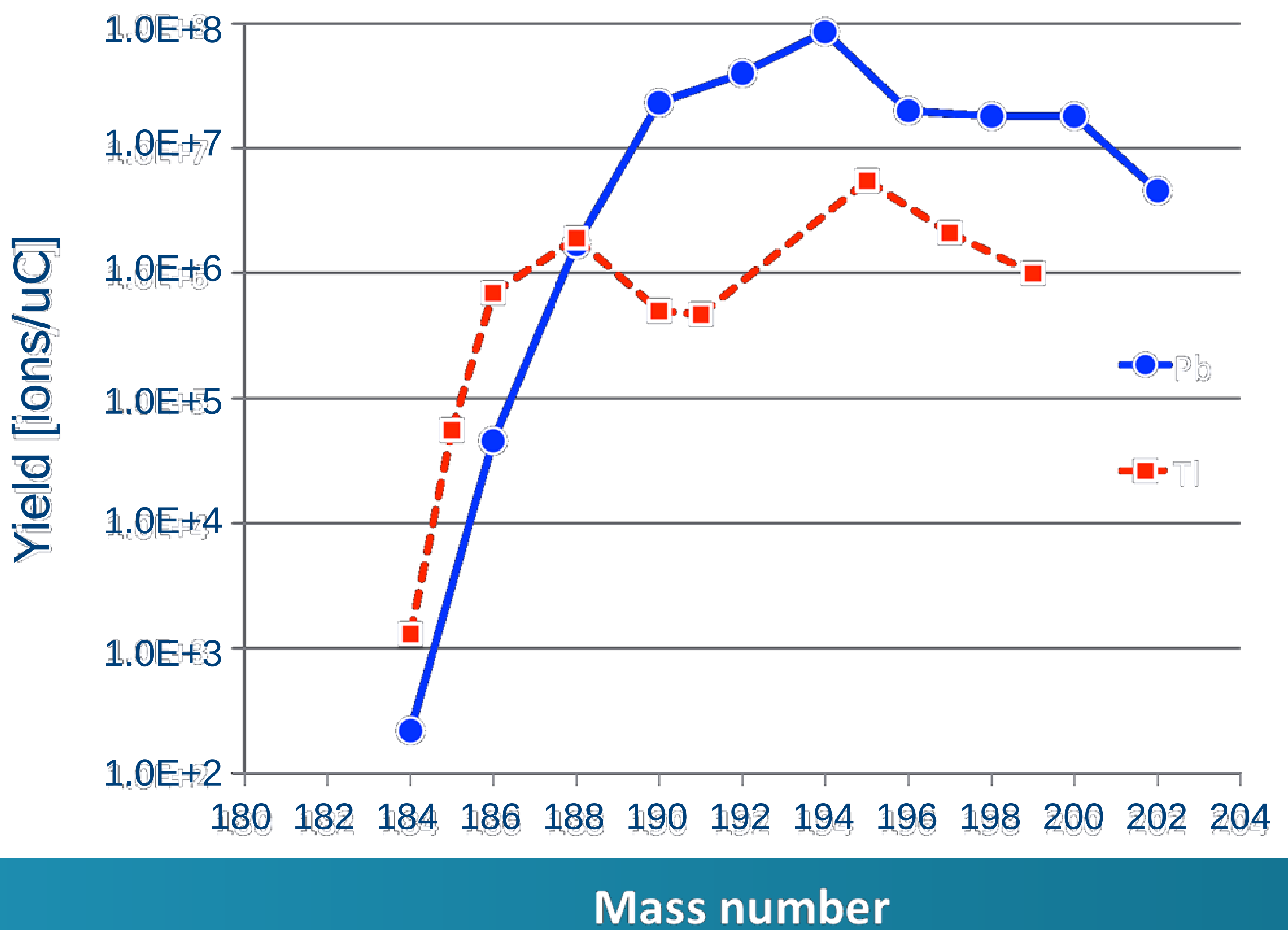
Extra slides

$^{188\text{-}196}Pb$ Coulex

ISOLDE yields



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