

Magnetic dipole moment of chiral bandhead in ^{128}Cs

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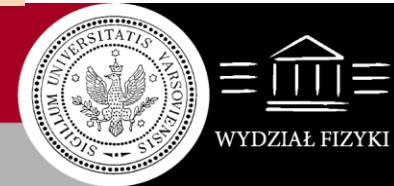
Zakład Fizyki Jądrowej

HIL (WARSAW)

LNL INFN (ITALY)

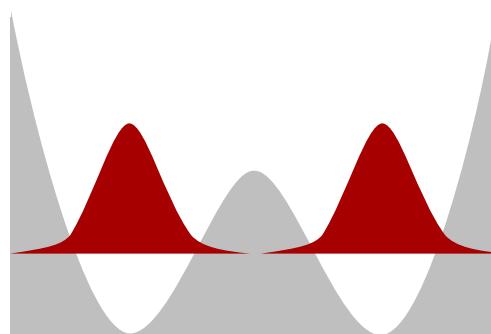
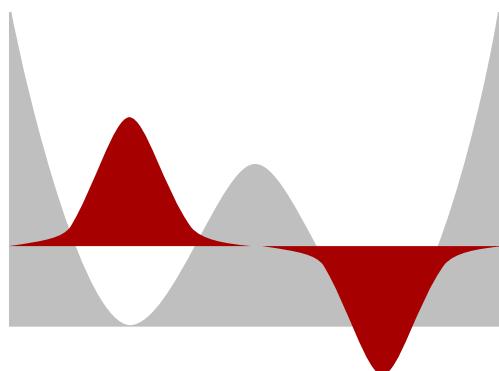
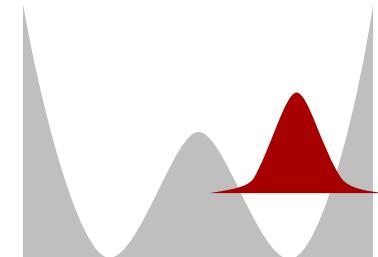
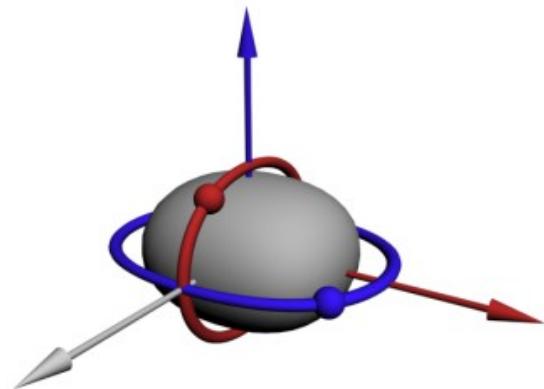
IPN (ORSAY)

NIPNE (ROMANIA)



Nuclear chirality - observables

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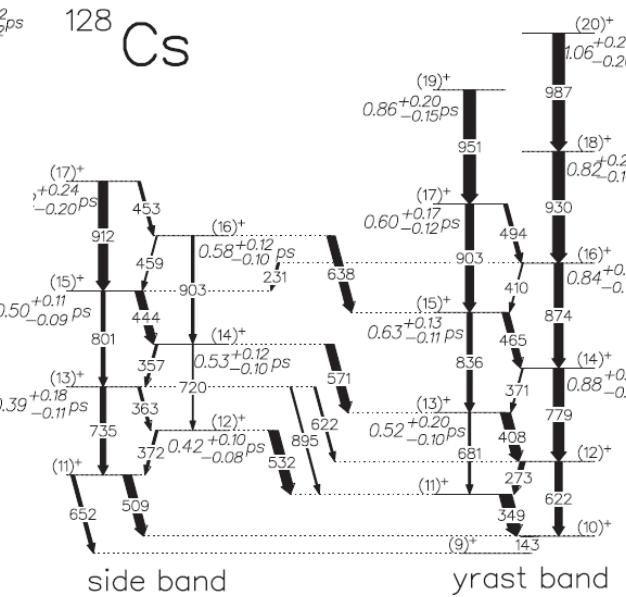
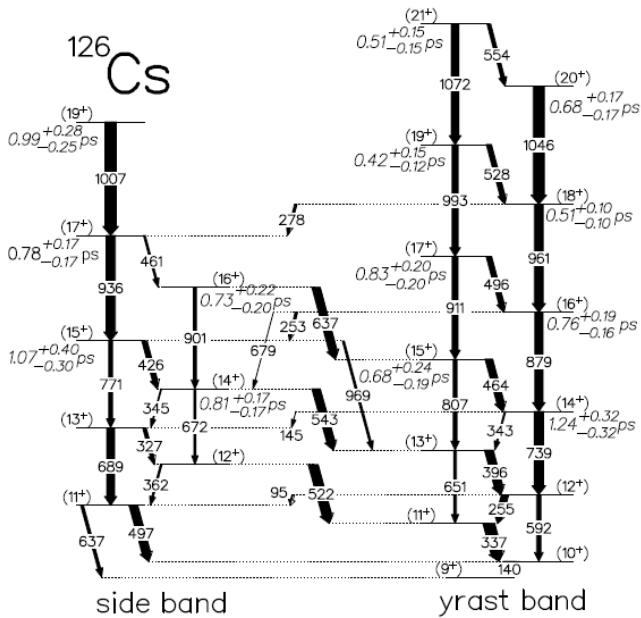


$$|I, M, +\rangle = \frac{1}{\sqrt{2}N_{I+}} (|I, M, L\rangle + |I, M, R\rangle)$$

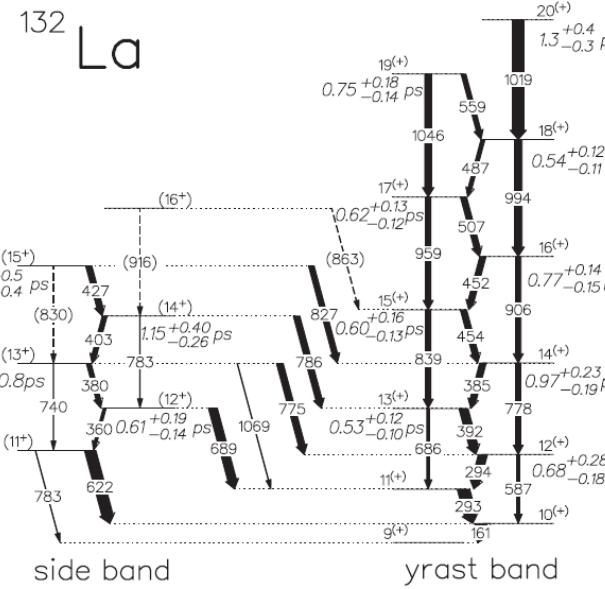
$$|I, M, -\rangle = \frac{i}{\sqrt{2}N_{I-}} (|I, M, L\rangle - |I, M, R\rangle)$$

Nuclear chirality - observables Cs, La

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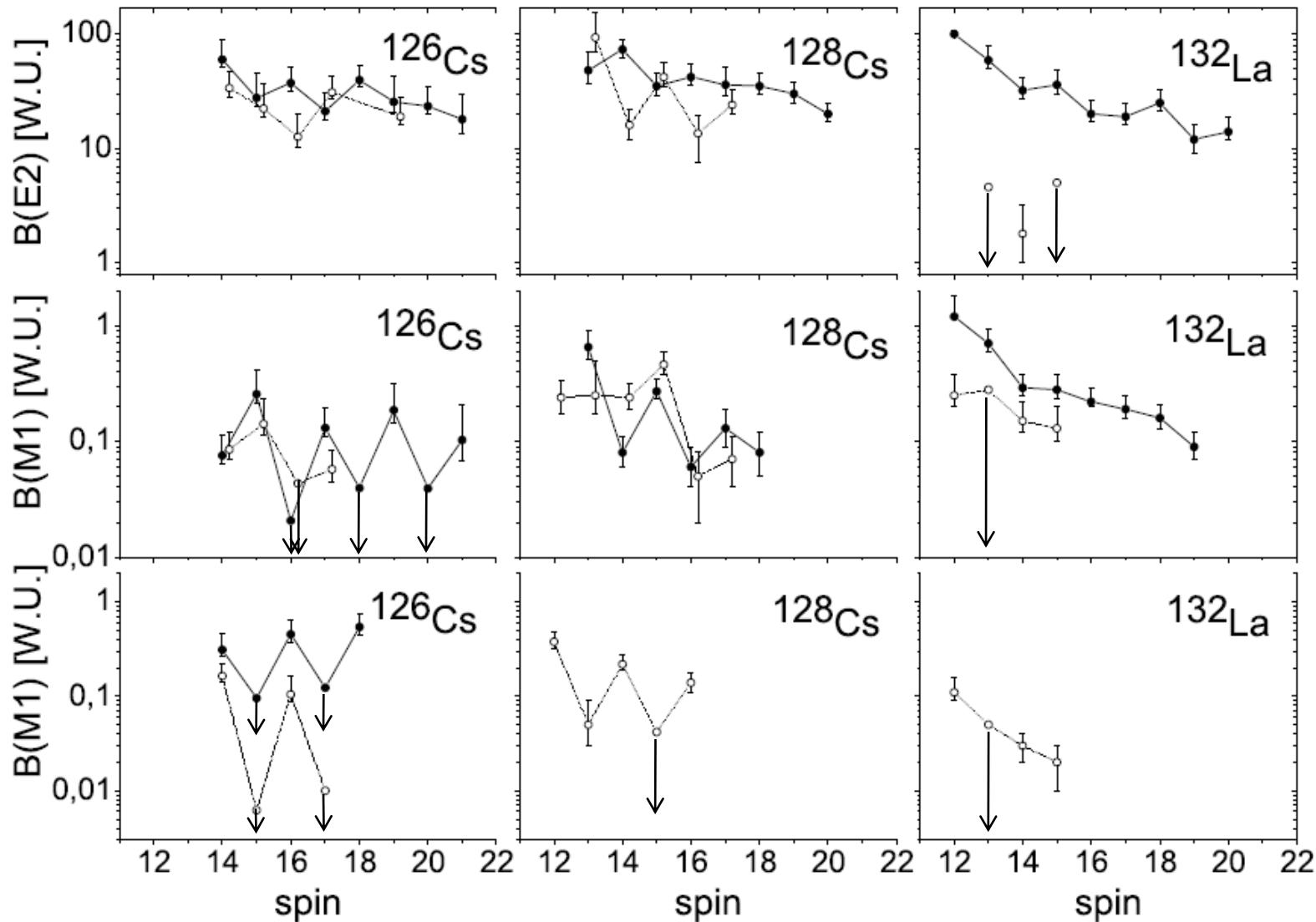
Lifetime results from the DSA experiments – warsaw cyclotron
Partner bands populated in fusion evaporation reaction
M1 interband transitions yrast \rightarrow side observed in ^{126}Cs
Energy separation in Cs Isotopes around 150 keV
 $\pi h_{11/2} \otimes vh_{11/2}^{-1}$ configuration

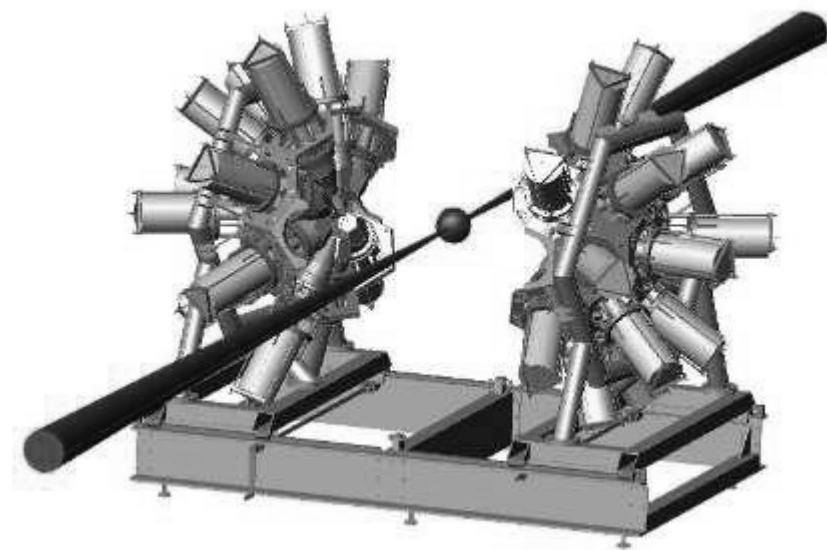
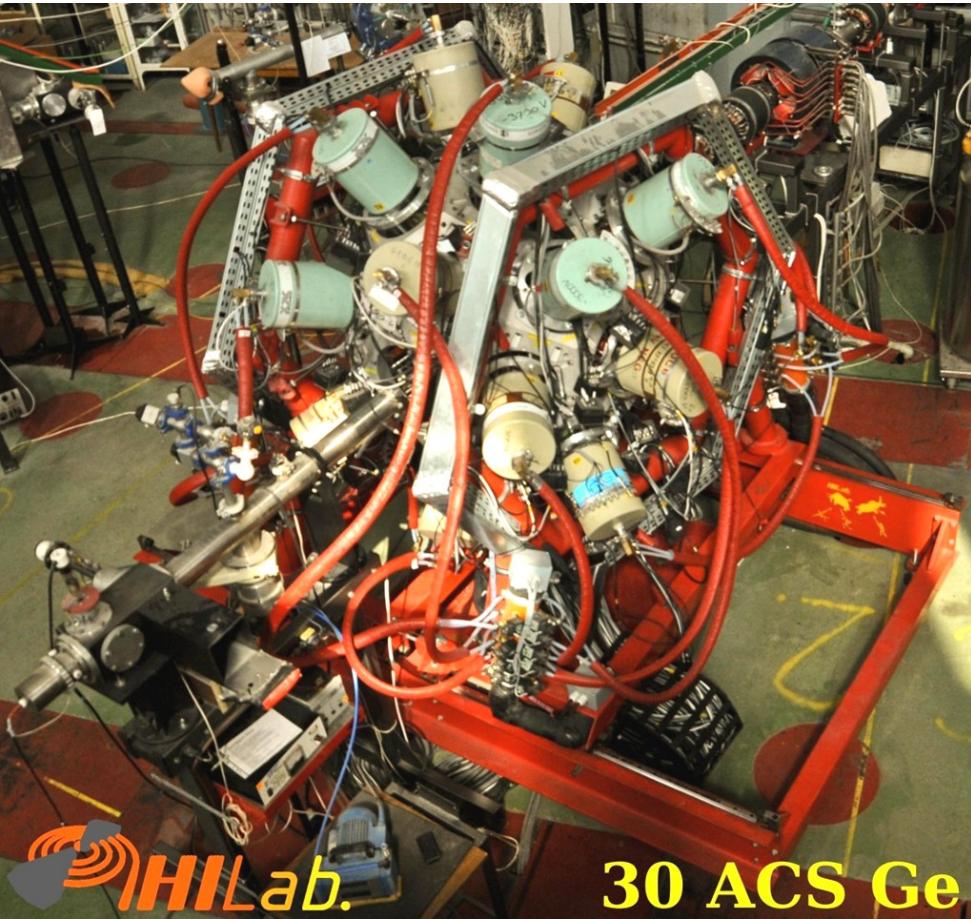


E.G. et al.,
 ^{128}Cs as the best example revealing the chiral symmetry breaking phenomenon
Phys. Rev. Lett. 97 (2006) 172501

Nuclear chirality - observables Cs, La

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J.Mierzejewski et al.,
Nucl. Instr. and Meth. A 659, 84 (2011);

E.G. et al.,

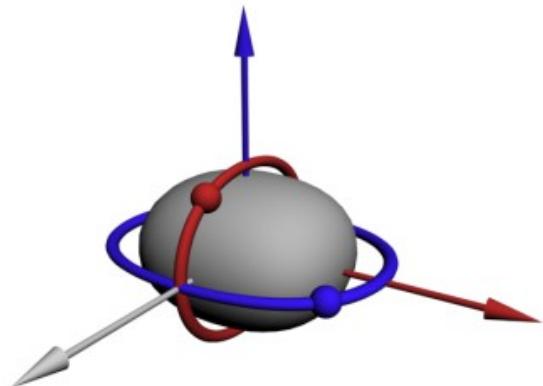
^{128}Cs as the best example revealing the chiral symmetry breaking phenomenon

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E.G. et al.,

Partner bands of ^{126}Cs – first observation of chiral electromagnetic selection rules

Phys. Lett. B703 (2011) 45

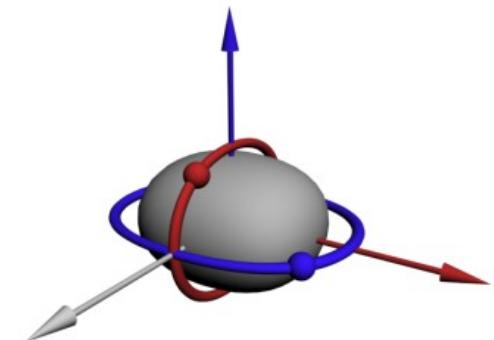


Is there an observable more directly related to the geometry of the three angular momenta vectors?

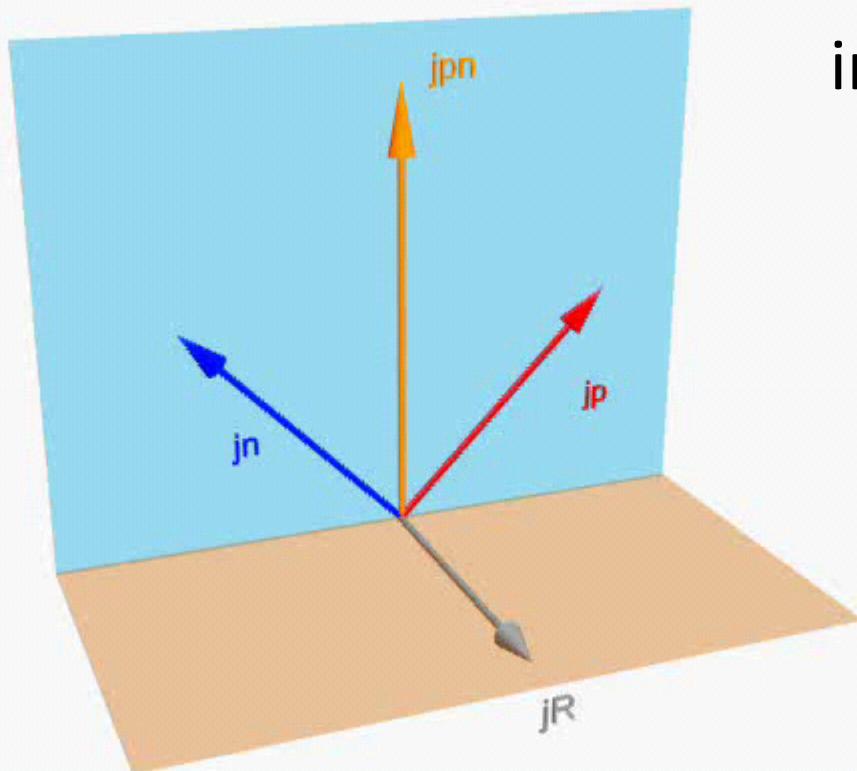
G-factor (3-components)

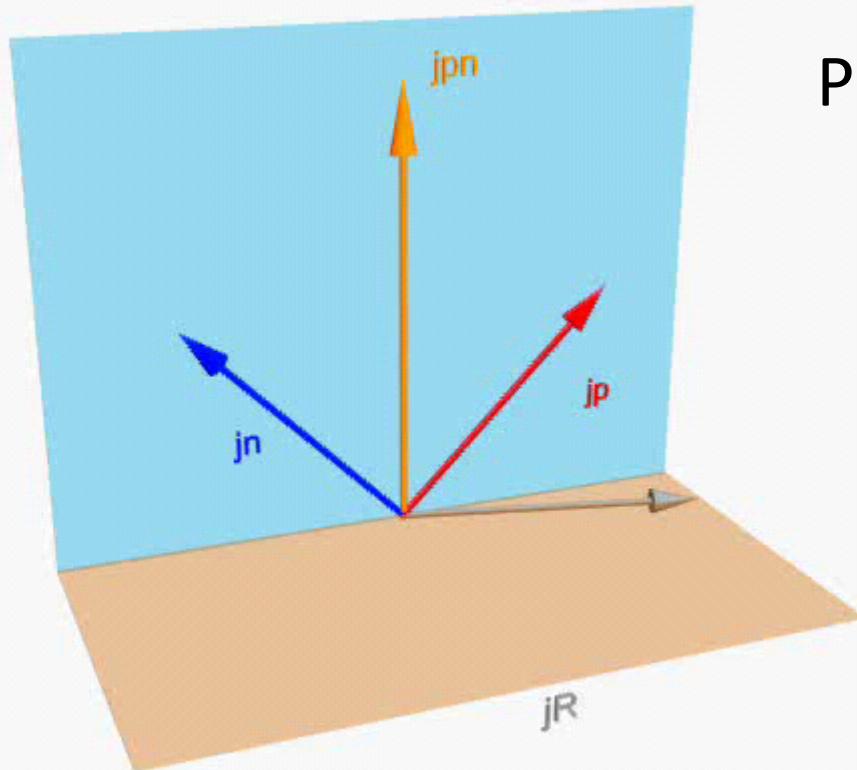
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$$\begin{aligned} g &= \frac{1}{2}(g_p + g_n + g_R) \\ &+ \frac{1}{J(J+1)} \frac{1}{2} j_p(j_p+1)(g_p - g_n - g_R) \\ &+ \frac{1}{J(J+1)} \frac{1}{2} j_n(j_n+1)(g_n - g_p - g_R) \\ &+ \frac{1}{J(J+1)} \frac{1}{2} j_R(j_R+1)(g_R - g_p - g_n) \\ &- \frac{1}{J(J+1)} (g_p \vec{j}_n \cdot \vec{j}_R + g_n \vec{j}_p \cdot \vec{j}_R + g_R \vec{j}_p \cdot \vec{j}_n) \end{aligned}$$

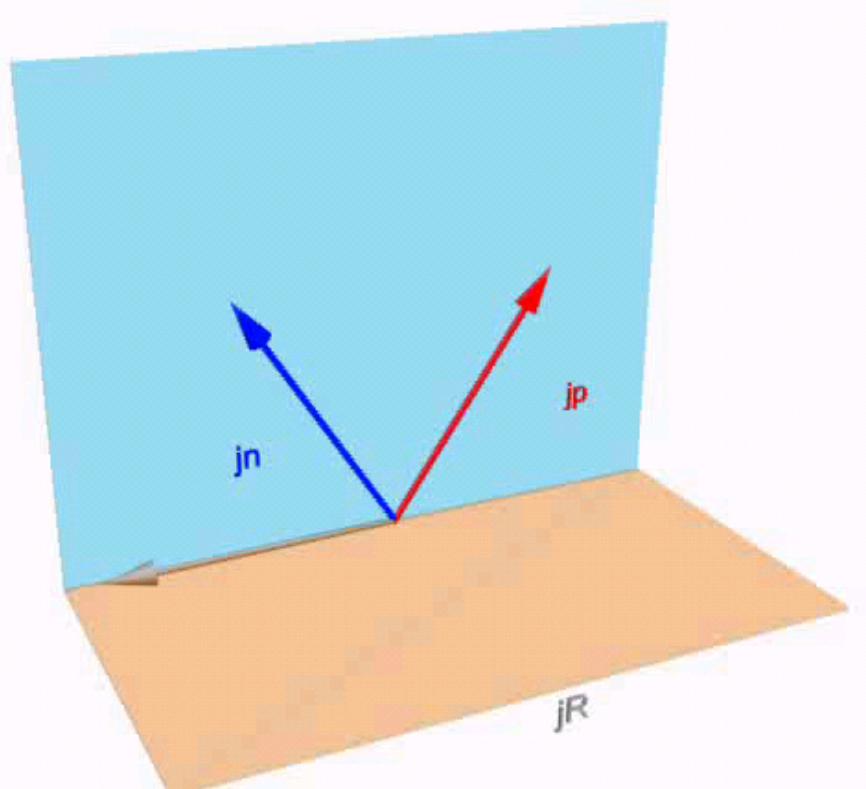


Chiral configuration
intermediate value of g-factor



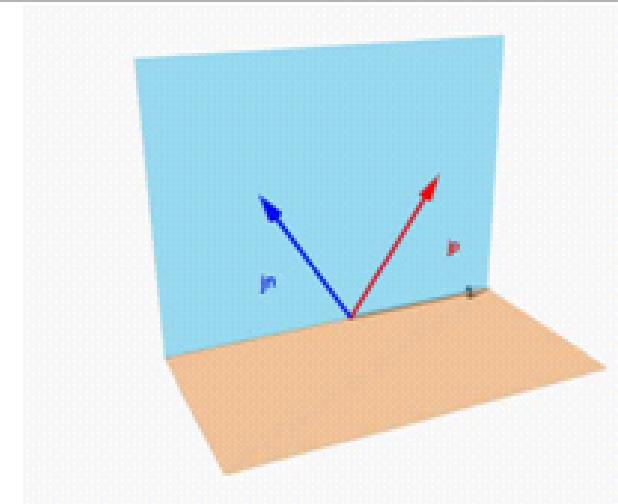
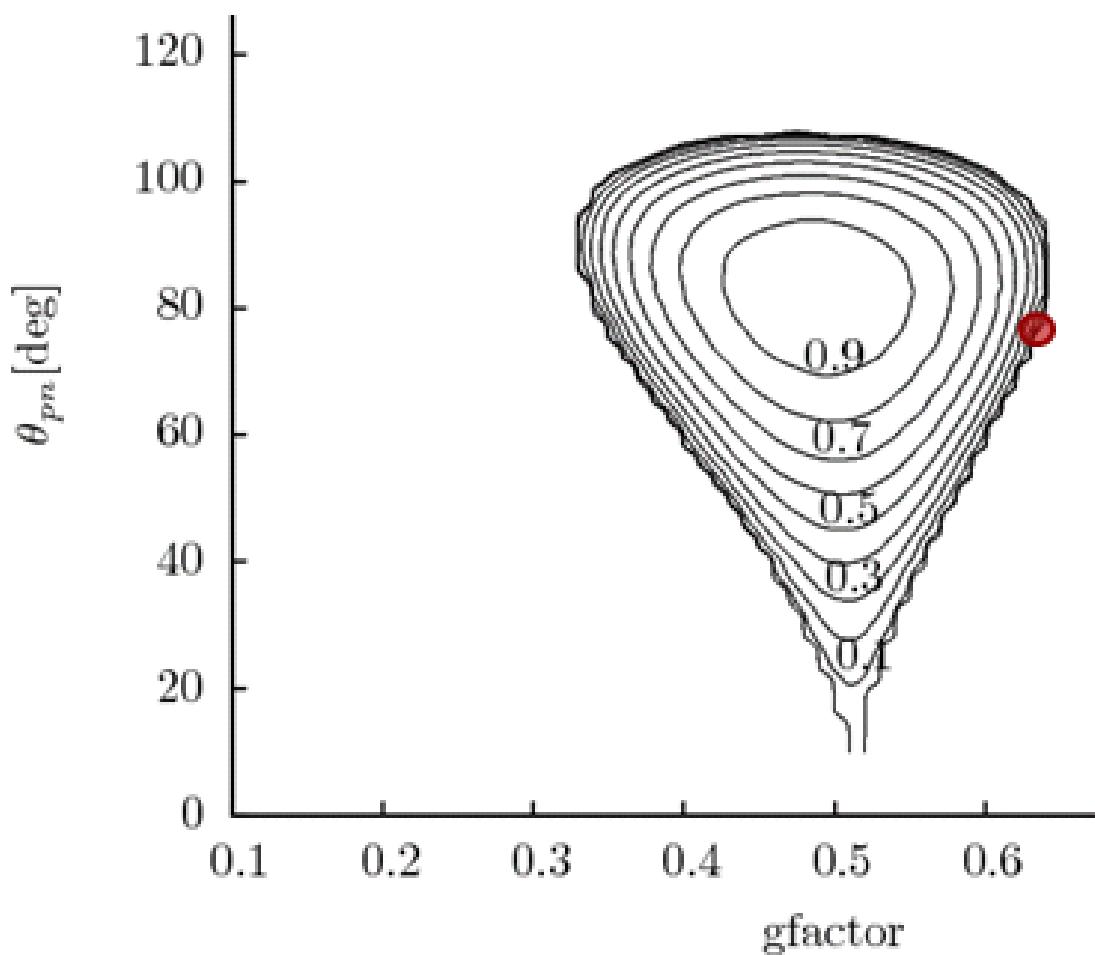


Planar (non-chiral) configuration
maximum value of g-factor



Opposite planar
(non-chiral) configuration

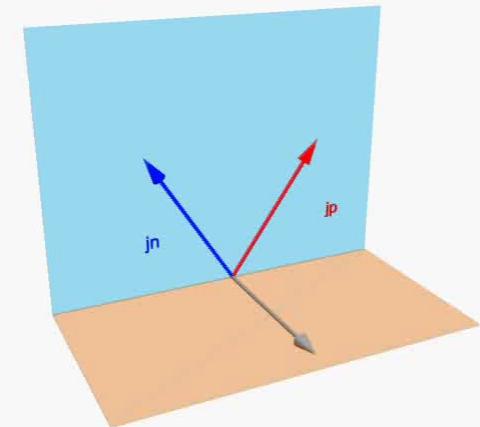
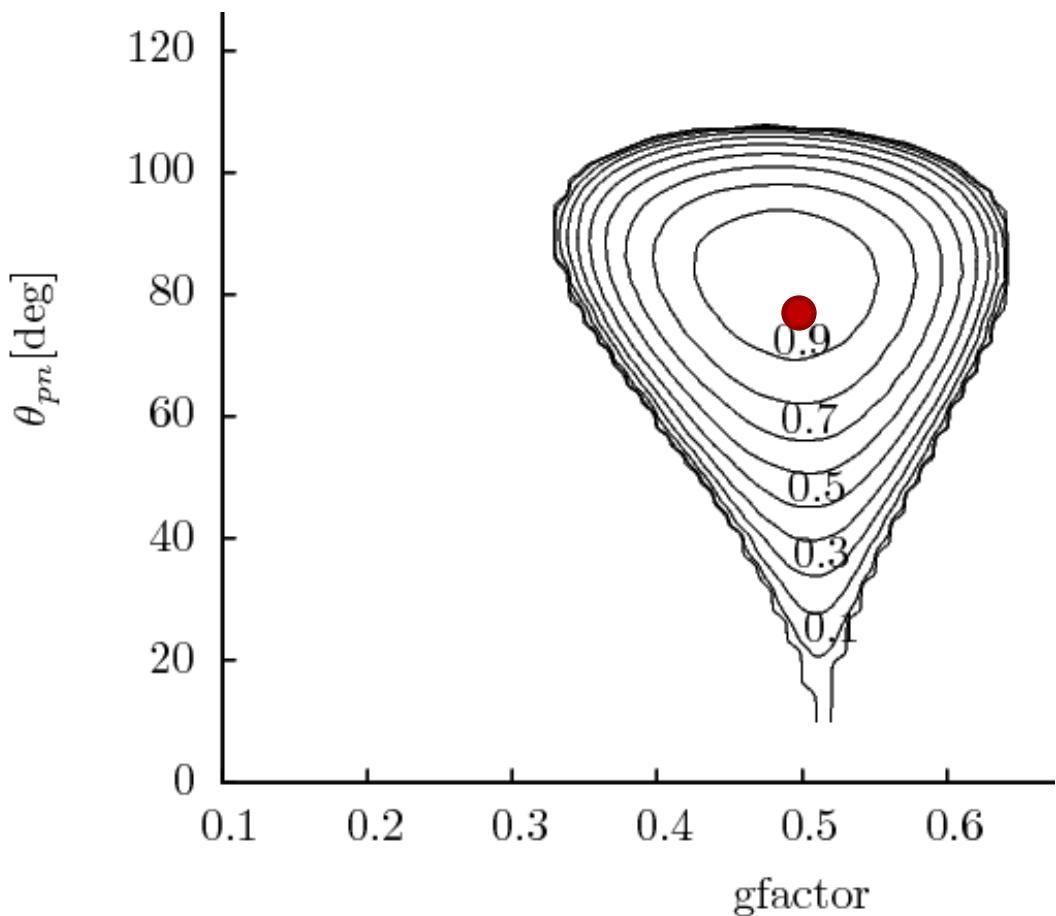
minimum value of g-factor



$$\langle \hat{o} \rangle = \frac{\langle (\mathbf{j}_p \times \mathbf{j}_n) \cdot \mathbf{j}_R \rangle}{\sqrt{\langle j_p^2 \rangle \langle j_n^2 \rangle \langle j_R^2 \rangle}}$$

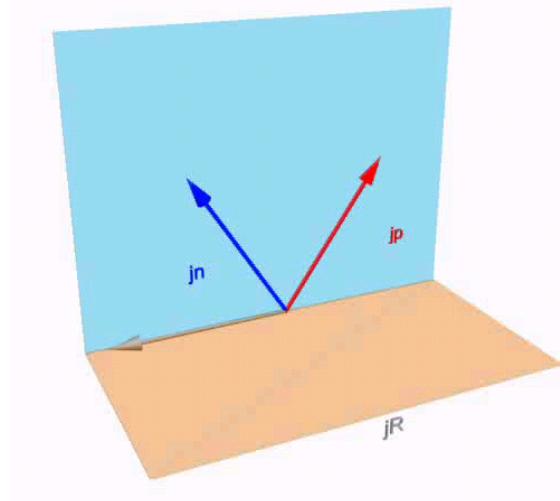
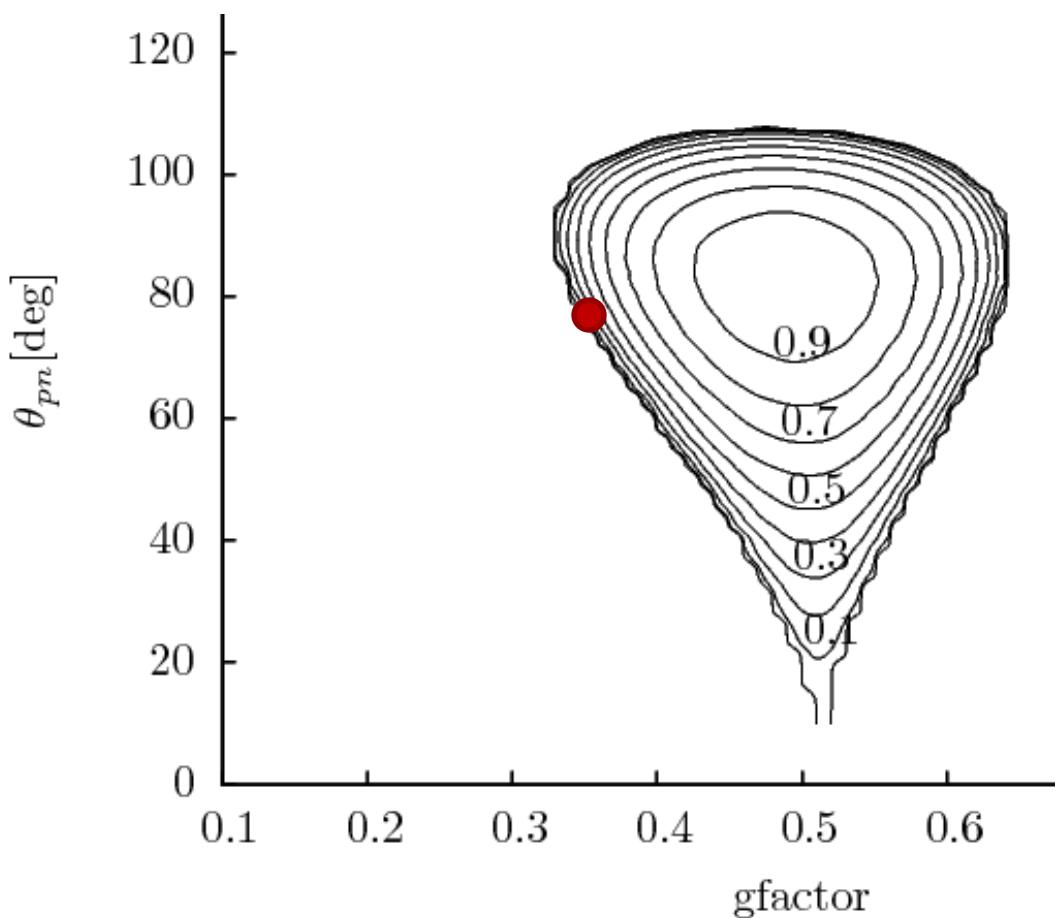
G-factor and handedness

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G-factor and handedness

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How to measure g ?
Initial spin alignment.

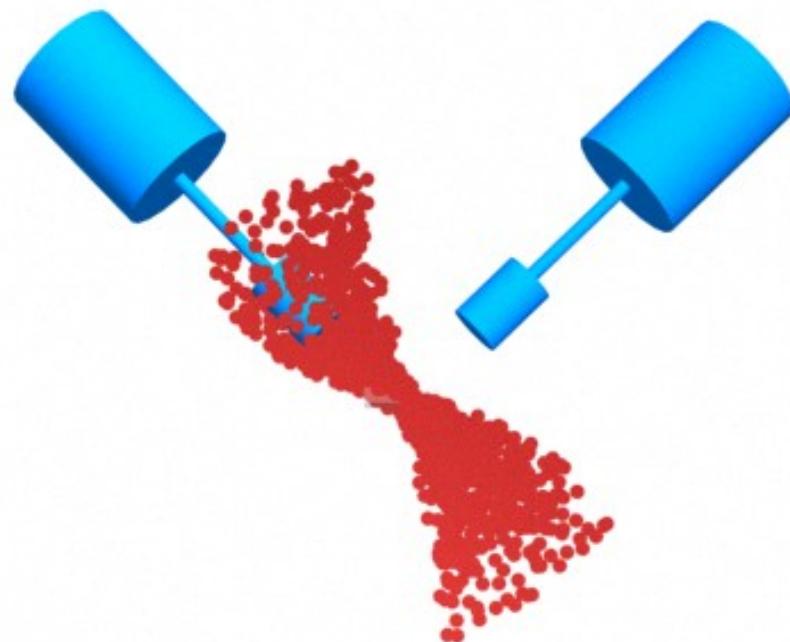
Angular distribution
of the gamma radiation

External magnetic field B...

... Interacts with the magnetic
moment

**TANDEM,
ALTO facility
ORsay**

Spin precession
TDPAD method



How to measure g ?

Initial spin alignment.

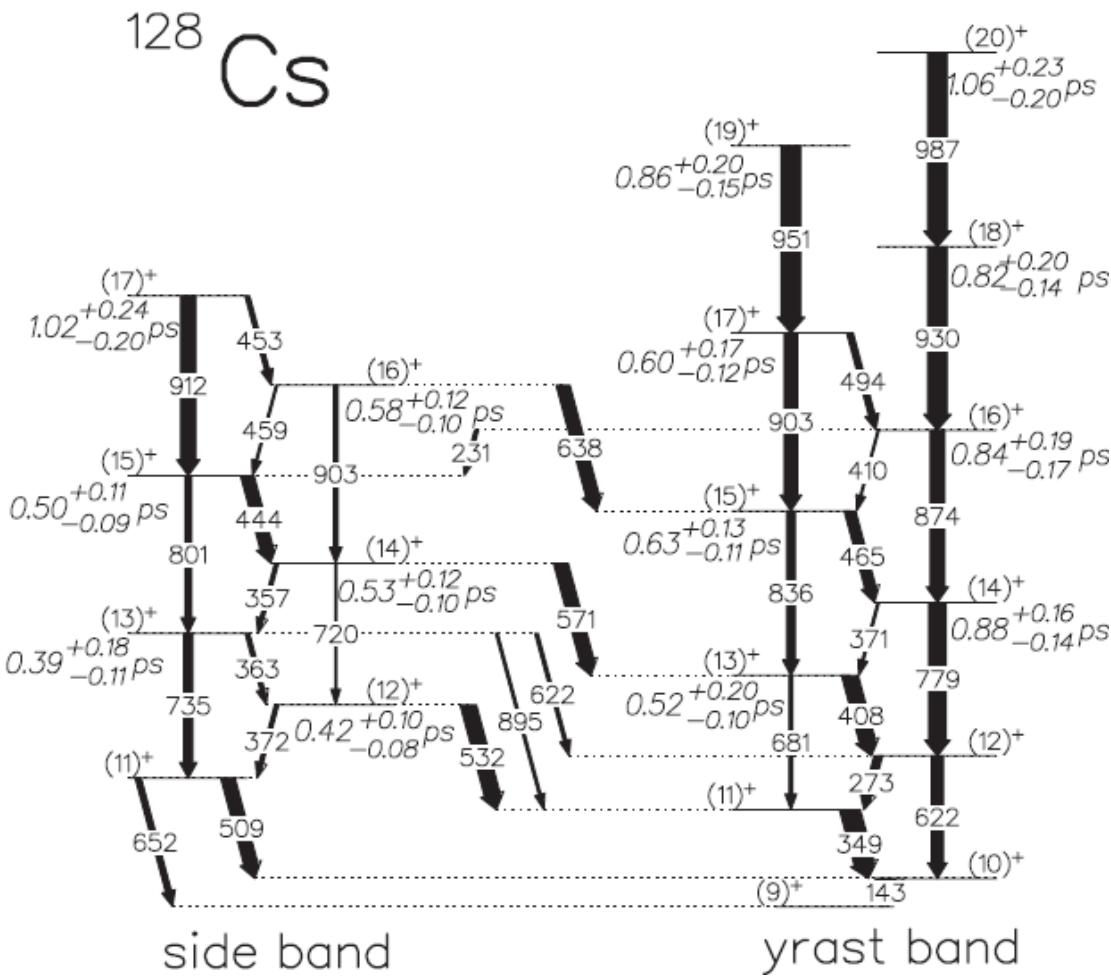
Angular distribution
of the gamma radiation

External magnetic field B...

... Interacts with the magnetic
moment

**TANDEM,
ALTO facility
ORSAY**

Spin precession
TDPAD method



TDPAD requirements

Timing HPGe

Strong external field B

Pulsed beam

Long level lifetime
(around 100ns)

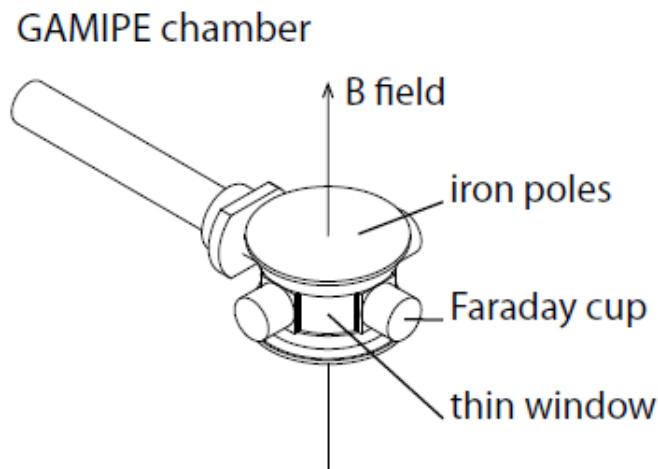
External B-field – GAMIPÉ chamber

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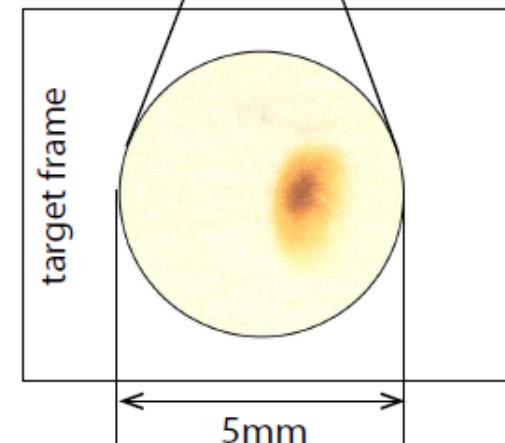
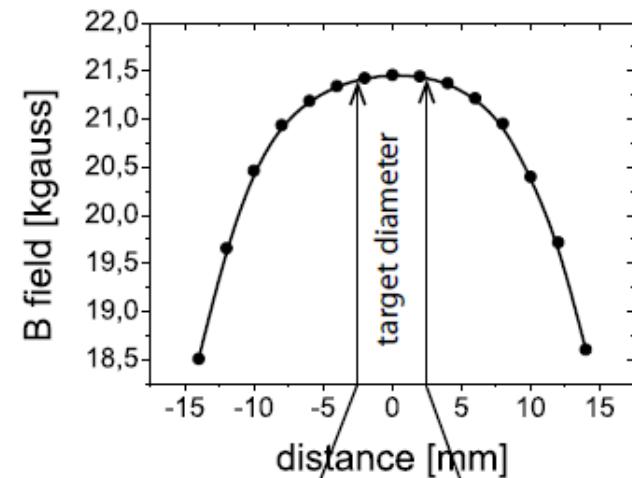
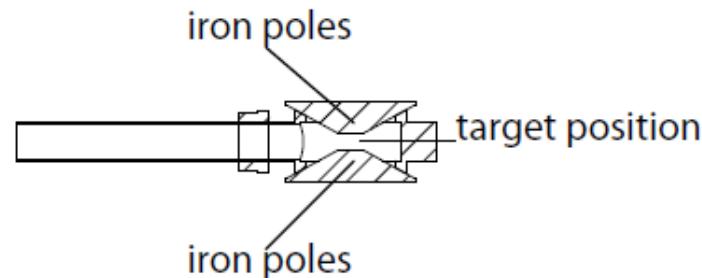
GAMIPÉ chamber NIPNE (Romania)

Fe Poles,

300% B field
amplification

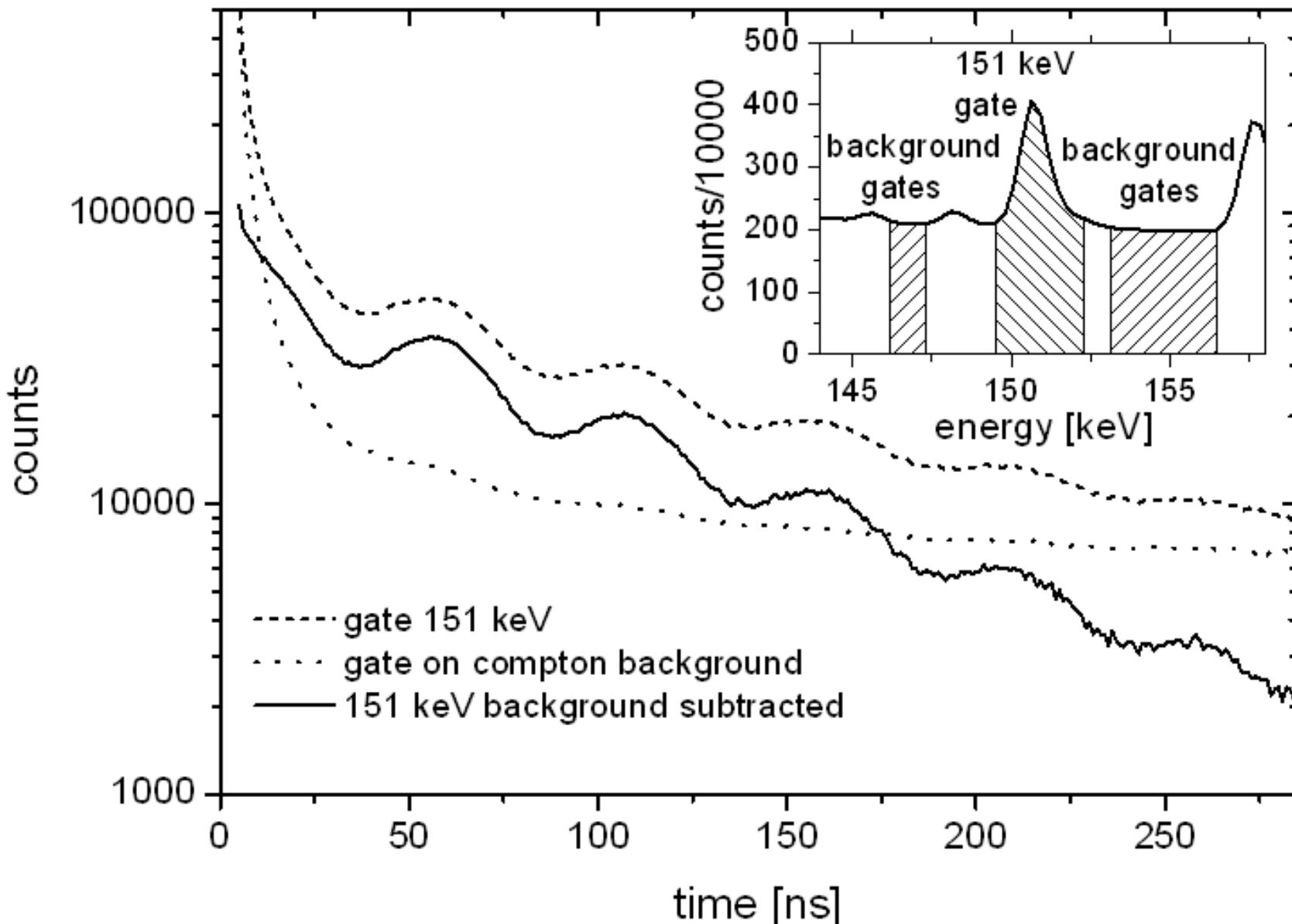


GAMIPÉ vertical section



Oscillating intensities

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SINGLE-COUPLING SCHEMES

$$|\langle \mathbf{j}_p \mathbf{j}_n \rangle j_{pn} \mathbf{j}_R, JM >$$

$$\langle (j'_p j'_n) j'_{pn} j'_R; J' M' | \vec{j}_p \cdot \vec{j}_n | (j_p j_n) j_{pn} j_R; JM \rangle = \delta_{J'J} \delta_{M'M} \delta_{j'_p j_p} \delta_{j'_n j_n} \delta_{j'_R j_R} \delta_{j'_{pn} j_{pn}} (-1)^{j_p + j_n + j_{pn}} \\ \times \sqrt{j_p(j_p+1)(2j_p+1)j_n(j_n+1)(2j_n+1)} \left\{ \begin{array}{ccc} j_p & j_n & j_{pn} \\ j_n & j_p & 1 \end{array} \right\}, \quad (15)$$

$$\langle (j'_p j'_n) j'_{pn} j'_R; J' M' | \vec{j}_p \cdot \vec{j}_R | (j_p j_n) j_{pn} j_R; JM \rangle = \delta_{J'J} \delta_{M'M} \delta_{j'_p j_p} \delta_{j'_n j_n} \delta_{j'_R j_R} (-1)^{j_R + j_p + j_n + J + 1} \\ \times \sqrt{(2j_{pn}+1)(2j'_{pn}+1)} \sqrt{j_p(j_p+1)(2j_p+1)} \sqrt{j_R(j_R+1)(2j_R+1)} \\ \times \left\{ \begin{array}{ccc} j_p & j_{pn} & j_n \\ j'_{pn} & j_p & 1 \end{array} \right\} \left\{ \begin{array}{ccc} j_{pn} & j_R & J \\ j_R & j'_{pn} & 1 \end{array} \right\}, \quad (16)$$

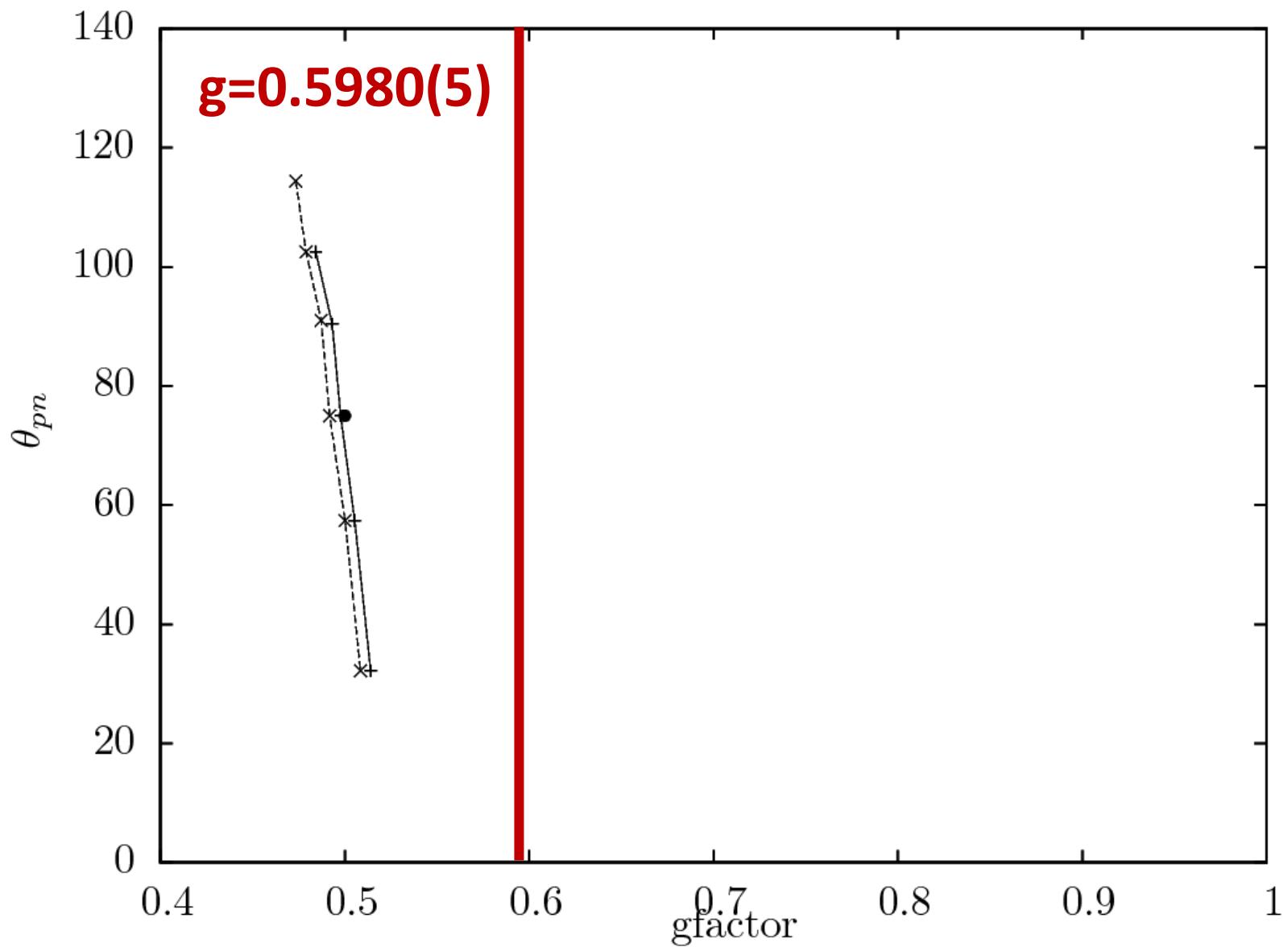
$$\langle (j'_p j'_n) j'_{pn} j'_R; J' M' | \vec{j}_n \cdot \vec{j}_R | (j_p j_n) j_{pn} j_R; JM \rangle = \delta_{J'J} \delta_{M'M} \delta_{j'_p j_p} \delta_{j'_n j_n} \delta_{j'_R j_R} (-1)^{j_R + j_p + j_n + J + 1 + j_{pn} + j'_{pn}} \\ \times \sqrt{(2j_{pn}+1)(2j'_{pn}+1)} \sqrt{j_n(j_n+1)(2j_n+1)} \sqrt{j_R(j_R+1)(2j_R+1)} \\ \times \left\{ \begin{array}{ccc} j_n & j_{pn} & j_p \\ j'_{pn} & j_n & 1 \end{array} \right\} \left\{ \begin{array}{ccc} j_{pn} & j_R & J \\ j_R & j'_{pn} & 1 \end{array} \right\}. \quad (17)$$

Quantum coupling 3 angular momenta

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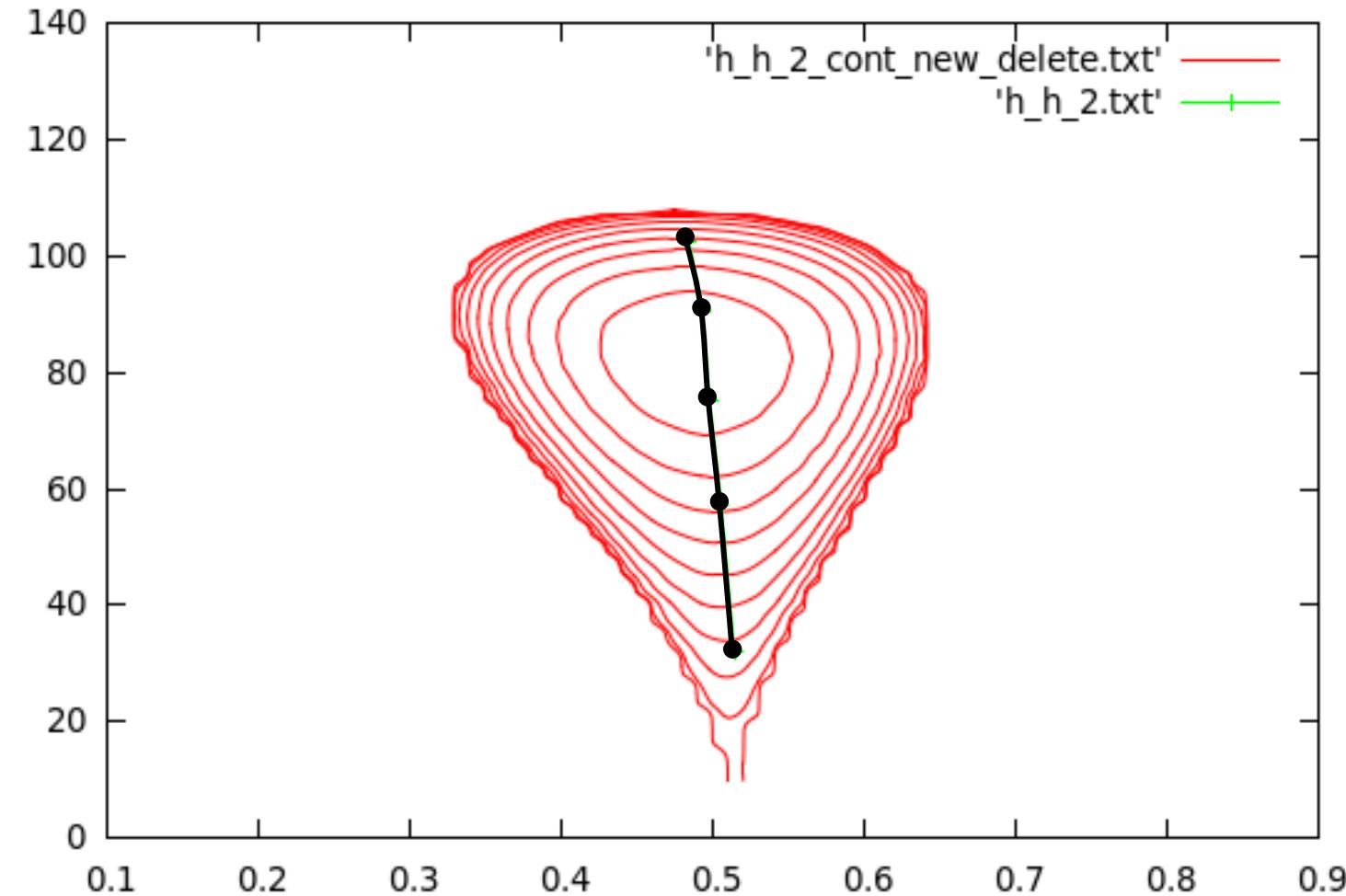
SINGLE-COUPLING SCHEMES

| configuration | j_{pn} [\hbar] | θ_{pn} [deg] | θ_{pr} [deg] | θ_{nr} [deg] |
|--|----------------------|---------------------|---------------------|---------------------|
| $\pi h_{11/2} \otimes \nu^{-1} h_{11/2} \otimes j_r = 0$ | 9 | 75.0 | none | none |
| $\pi h_{11/2} \otimes \nu^{-1} h_{11/2} \otimes j_r = 2$ | 7 | 102.5 | 61.4 | 61.4 |
| | 8 | 90.4 | 78.2 | 78.2 |
| | 9 | 75.0 | 95.9 | 95.9 |
| | 10 | 57.4 | 116.3 | 116.3 |
| | 11 | 32.2 | 145.0 | 145.0 |
| $\pi h_{11/2} \otimes \nu^{-1} h_{11/2} \otimes j_r = 4$ | 6 | 114.4 | 74.8 | 74.8 |
| | 7 | 102.5 | 82.5 | 82.5 |
| | 8 | 90.4 | 91.0 | 91.0 |
| | 9 | 75.0 | 100.7 | 100.7 |
| | 10 | 57.4 | 112.0 | 112.0 |
| | 11 | 32.2 | 125.4 | 125.4 |



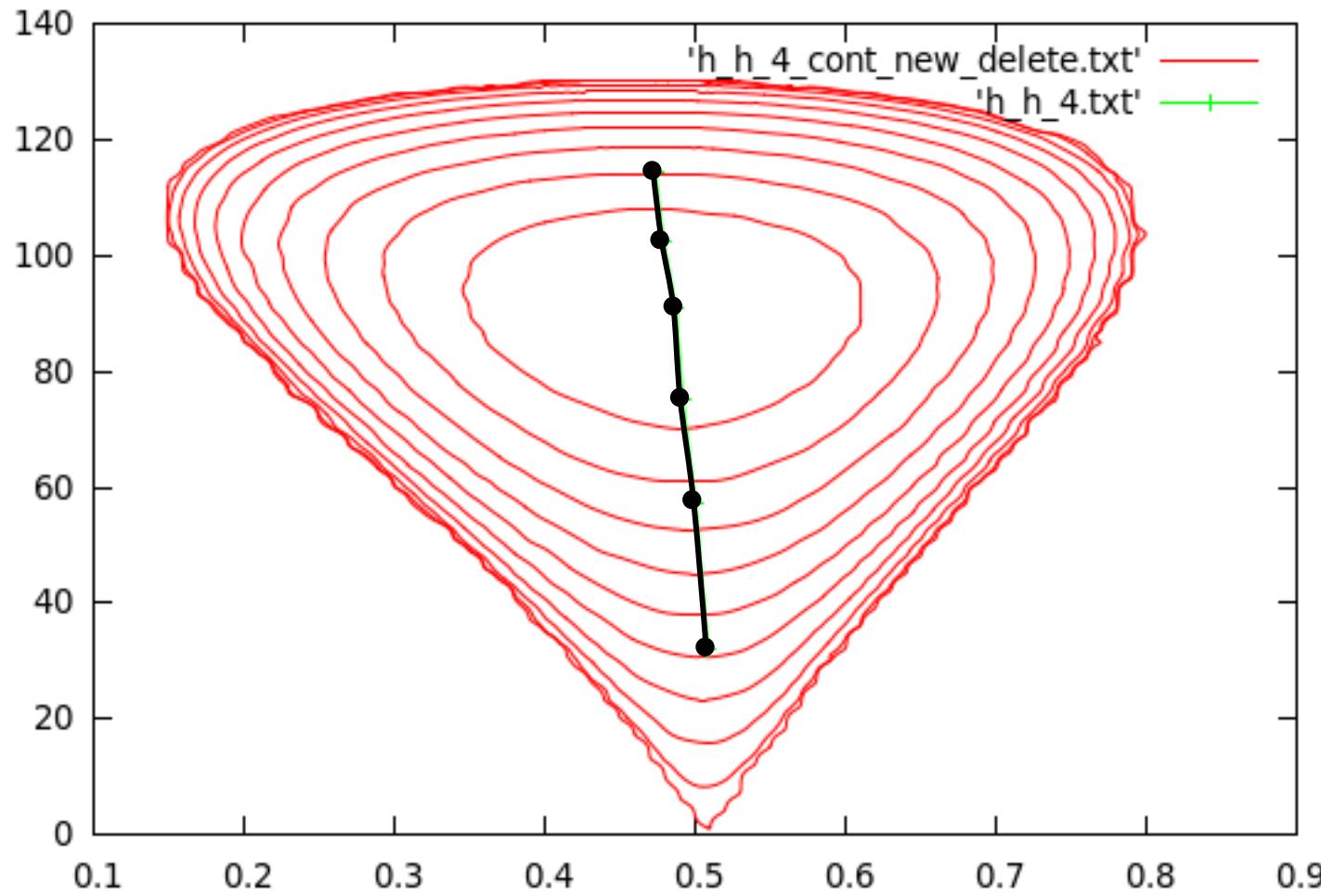
Quantum single-coupling schemes

Always maximally chiral ?!



Quantum single-coupling schemes

Always maximally chiral ?!

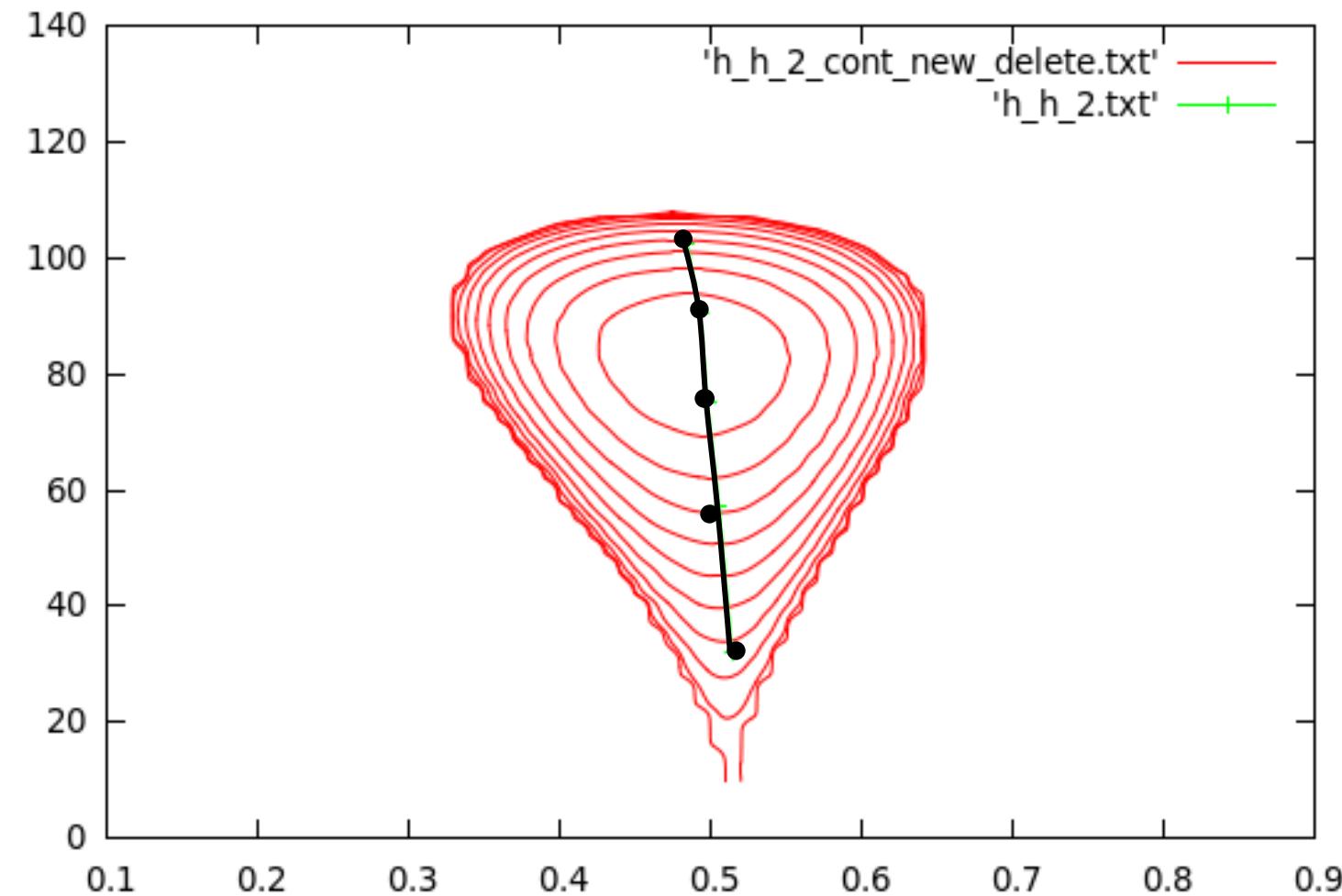


2010 → 2016

Did we choose a special set of coupling?

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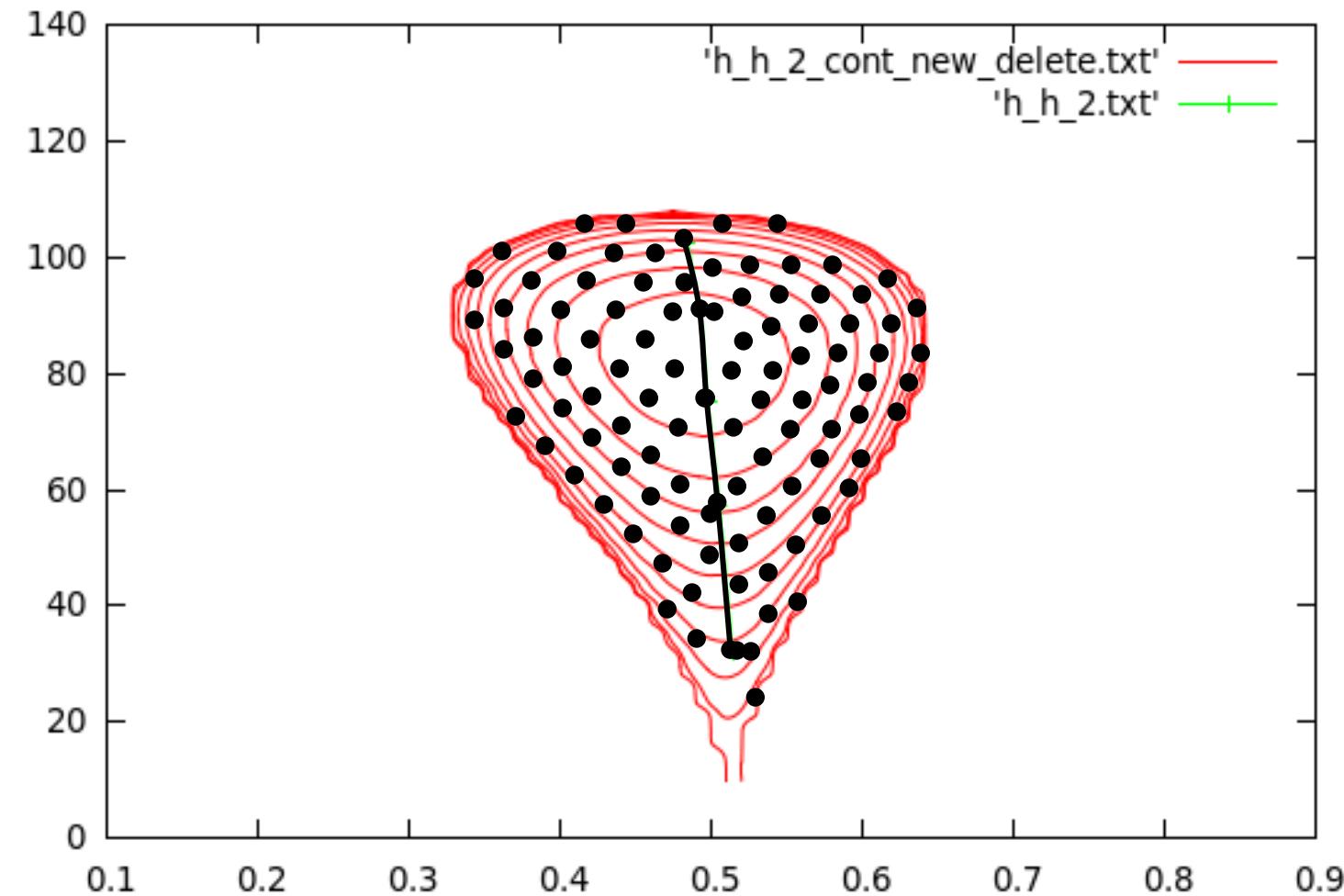
$$(A + B) + C = (B + C) + A$$



Did we choose a special set of coupling?

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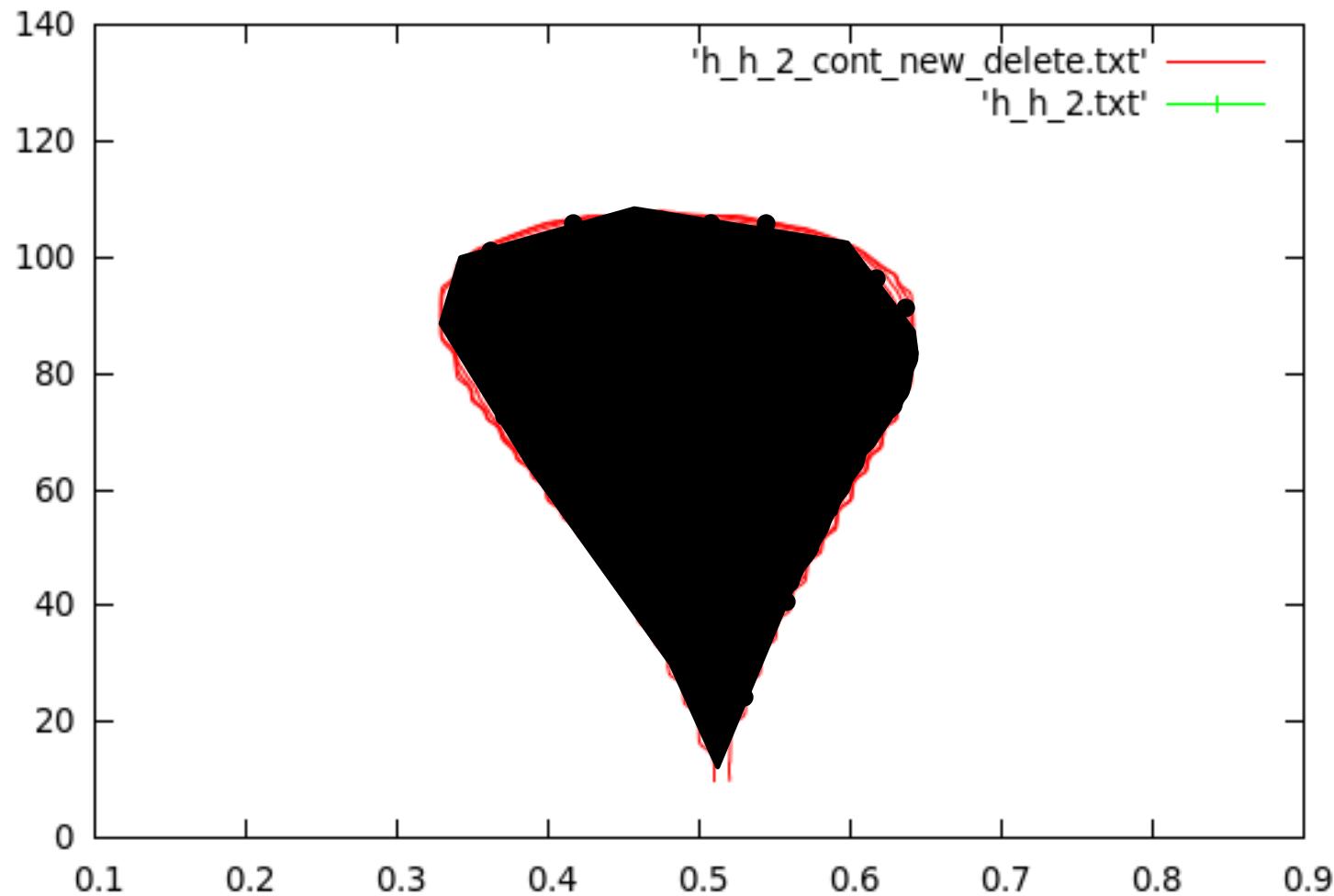
$$|(j_p j_n) j_{pn} j_R, JM > \neq |(j_n j_R) j_{nR} j_p, JM >$$



Closer to semi-classical picture

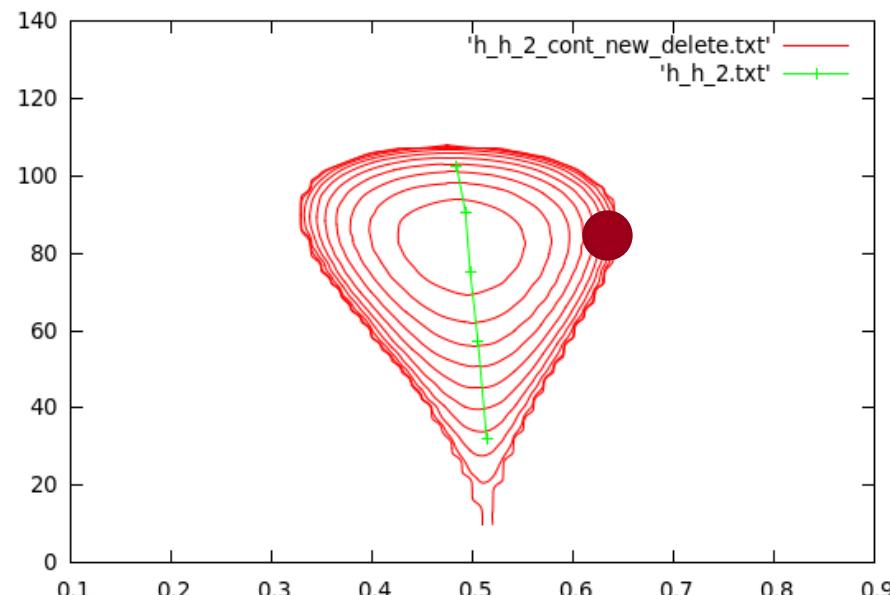
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$$|JM\rangle = \sum_{j_p, j_n, j_{pn}, j_R} c_J(j_p, j_n, j_{pn}, j_R) |(j_p j_n) j_{pn} j_R; JM\rangle$$



CONCLUSION: non-chiral configuration!

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$j_p \times j_n \times R=0$

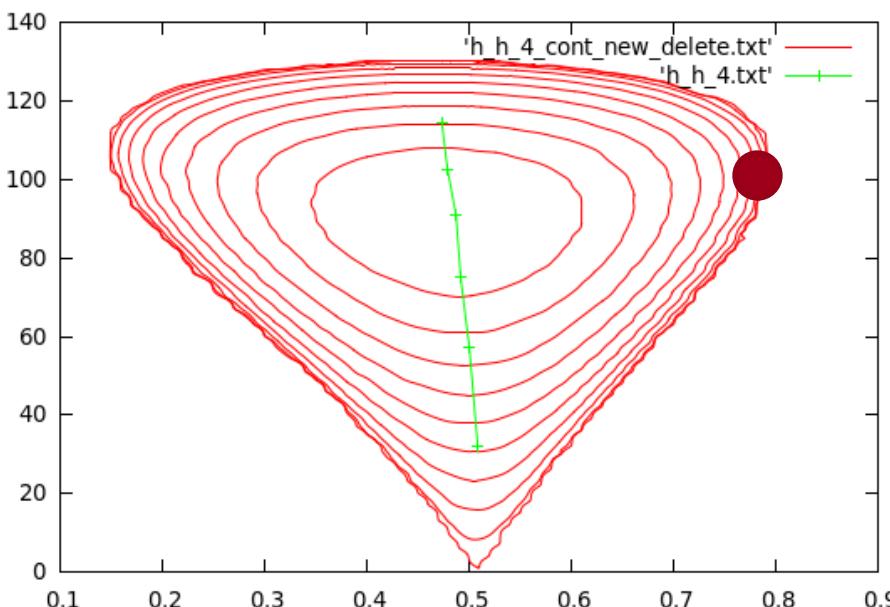
$g=0.5$

$j_p \times j_n \times R=2$

$g=0.65$

$j_p \times j_n \times R=4$

$g=0.80$



Eksperiment

$g=0.59$

The chiral bandhead is
NON- CHIRAL

| | |
|--|----------------------|
| M.Kowalczyk, M.Kisieliński, J.Srebrny , L. Próchniak | ŚLCJ |
| E.Grodner | WARAW UNI. |
| C. Ur, F. Recchia | INFN PADOVA |
| S. Aydin | AKSARAY, INFN |
| G. Georgiev, E. Fiori, R. Lozeva | IPN ORSAY |
| | |
| M. Bujor | NIPNE |
| Ch. Droste | ZFJ |
| G. Rohoziński | ZTJA |
| L.Próchniak | ŚLCJ |
| J. Meng, Q. B. Chen ,S. Zhang,L. F. Yu , P. Zhao | Beihang UNI. |