Nuclear moments and transition probabilities in the vicinity of the doubly magic $^{208}\text{Pb}$ by off-line measurements.

The case of $^{210}\text{Pb}$.


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Shell closures, B(E2)’s and nuclear moments

- $^{208}\text{Pb}$ – accepted as robust doubly-magic nucleus while $^{16}\text{O}$ and $^{40}\text{Ca}$ are soft towards particle-hole excitations

- Energies – good indicators, reproduced by the theories, but not strongly dependent on the interactions

- Transition probabilities (B(E2)’s) – first order test to the theories

- Nuclear magnetic moments ($\mu$) – the real measure of the purity of the wave functions!

- Combined $B(E2)$ and $\mu$ - the ultimate experimental test – still missing data for $2^+$ states close to $^{208}\text{Pb}$!
Doubly-magic + 2 nucleons

- Nuclei with 2 nucleons outside doubly-magic core – a test for basic shell-model assumptions.

- Low-excitation states – used to determine two-body residual interactions \( \approx \) Recoupling of the spins of pure \( j^2 \) configuration.

- Transition probabilities for a simple \( j^2 \) configuration:

\[
B(E2; J_i \rightarrow J_i - 2) = 4(2J_i - 3) \left\{ \frac{j}{J_i} \left( \frac{J_i - 2}{2} \right)^2 \right\} |\langle j \| T(E2) \| j \rangle|^2
\]

- Magnetic moments: \( g(J) = g(j) \) – identical \( g \) factors for all states in the multiplet
Some discrepancies for the B(E2) of the $2^+$ states in $^{18}$O and $^{92}$Zr

- **B(E2) of $2^+$ in $^{210}$Pb** – a measurement from 50 years ago with big error bar. Lower than expected value.

- *g* factors of single-particle states (*odd-mass nuclei*) – very close to the Schmidt limits

- *g* factors of $2^+$ states in $^{18}$O, $^{42}$Ca and $^{92}$Zr ⇒ strong collective contributions

- *g*(2$^+$) $^{210}$Pb – single-particle? *How pure???
The aim of the present experiment is to:

- Determine the transition probabilities (B(E2)) for the 2\(^+\) and 4\(^+\) states in \(^{210}\)Pb (< 5% accuracy)
- Measure the \(g\) factor of the 2\(^+\) state in \(^{210}\)Pb with \(\sim 5\%\) accuracy
Experimental approach

- Post-accelerated (~5 MeV/u) \(^{210}\text{Pb}\) (\(T_{1/2} = 22\text{y}\)) beam → no protons required, any “old” ISOLDE target can be used
- \(B(E2)\) – from Coulomb excitation (normalization to target excitation &/or Rutherford)
- \(g\) factor – from Recoil In Vacuum (RIV) measurement

Miniball plunger:
- used to define the electron – ion interaction time.
- \(g\)-factor sensitive distances ~ 1 – 5 ps.
- Plunger lifetime information – complementary to the Coulex \(B(E2)\) value
Plunger details

- **target** – any “good plunger material” between Mg (Z=12) and Ni (Z=28)
- **stopper** – high-Z material (e.g. Au) – sufficiently thick to stop the $^{210}\text{Pb}$ beam and thin enough to let the recoiling target nuclei go through
- **independent target** ($^{120}\text{Sn}$) $\rightarrow$ for the B(E2) of the $4^+$ state
- CD angular coverage – $14^\circ$ – $40^\circ$
- count-rate calculations (assuming $^{58}\text{Ni}$ target and $2\times10^5$ pps $^{210}\text{Pb}$ beam):
  - 3200 $\gamma$’s per day in the $2^+ \rightarrow 0^+$ transition
  - 60 $\gamma$’s per day in the $4^+ \rightarrow 2^+$ transition
  - **5 plunger distances** needed – for the RIV measurement
- $^{120}\text{Sn}$ target and $2\times10^5$ pps $^{210}\text{Pb}$ beam $\rightarrow$ 340 $\gamma$’s per day in the $4^+ \rightarrow 2^+$ transition
Beam-time request

- **NO proton beam requested!!**

- **15 UT's** (5 days) of 5 MeV/u $^{210}$Pb beam for measuring the $B(E2)$ and the $g$ factor of its $2^+$ state

- **3 UT's** (1 day) for measuring the $B(E2)$ of its $4^+$ state

- **12 UT's** (4 days) of $^{207}$Pb beam (e.g. from mass marker) for calibration of the RIV interaction

- **Standard $^{22}$Ne run** – for determining the position of the Miniball detectors (overnight)

$\rightarrow$ 30 UT’s off-line run requested