New evidence for alpha clustering structure in the ground state band of ^{212}Po

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Physics case

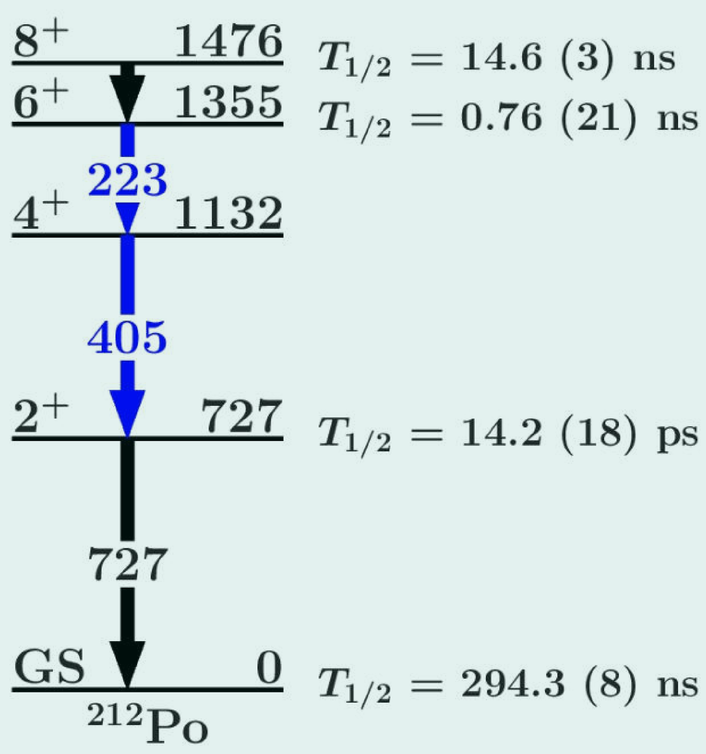
^{212}Po lies two protons and neutrons outside the doubly-magic nucleus ^{208}Pb.

The energy of the low-lying exited states can be well described by the shell-model approach, but experimental properties, such as the large α-decay width of the ground state, cannot described by this approach.

This has motivated the description of this nucleus by a strongly mixing shell-model and α-cluster configurations [2].

B(E2) values for the decays of the low-lying yrast states cannot be described by any of the models.

The B(E2; $4_1^+ \rightarrow 2_1^+$) and therefore the lifetime of the 4_1^+ state are missing.



Partial level scheme of ^{212}Po. Lifetimes are taken from Ref. [1]

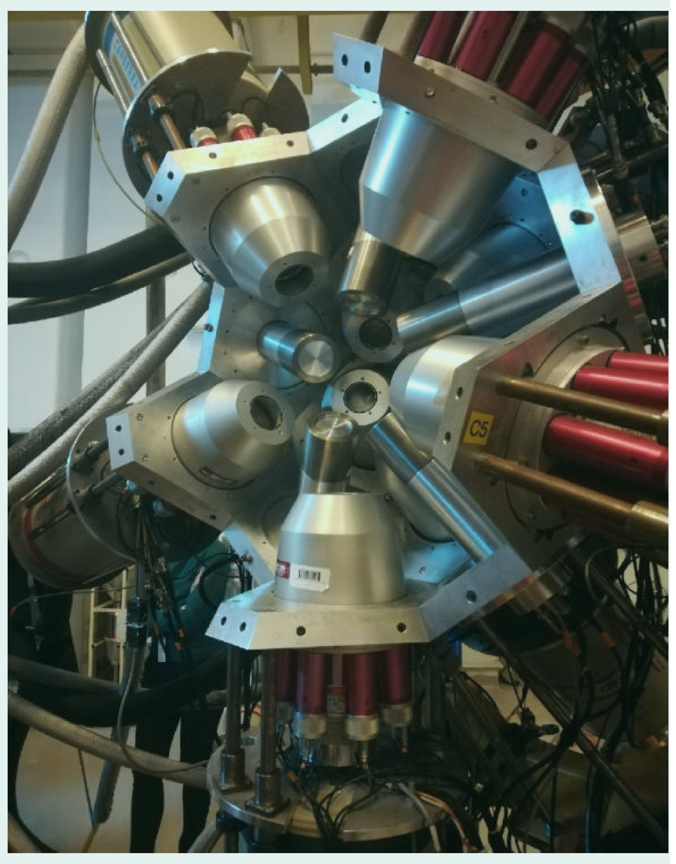
Experimental setup

α-transfer reaction: A beam of ^{10}B at energy of 51 MeV was impinged on a ^{208}Pb target (9.65 mg/cm^2). The γ-rays were detected by ROSPHERE in coincidence with the ^{6}Li ejectile, detected in SORCERER.

ROSPHERE γ-ray detector array [6]: Consists of 15 high-purity Germanium detectors (HPGe) and 10 $LaBr_3$(Ce) fast-timing scintillator detectors.

SORCERER particle detector array [7]: 6 Silicon photodiodes cover an angular range from 121.7 degree to 163.5 degree with respect to the beam direction.

Trigger conditions: Two HPGe events or one Si-$LaBr_3$(Ce) event

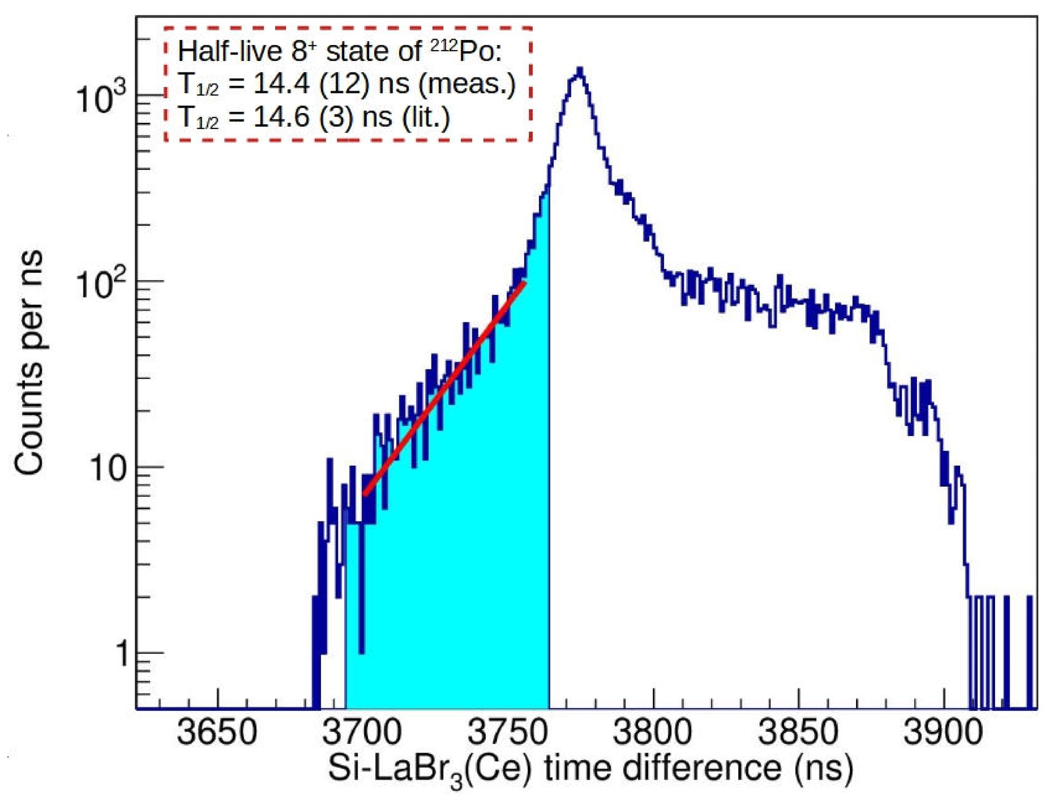


Half of the ROSPHERE array.

Separation of ^{212}Po

Contaminations of other reaction channels, such as fusion-evaporation (^{214,215}Fr) or one proton transfer (^{209}Bi), are too strong for a clean fast-timing analysis.

A clean measurement of the 4_1^+ state lifetime is possible by taking advantage of the isomeric 8$^+$ state and the time difference between the Silicon and $LaBr_3$(Ce) events.



Lifetime analysis

The lifetime of the first 4$^+$ state is assumed to lie in the 100 ps-region → Well suited for a *centroid shift lifetime* measurement.

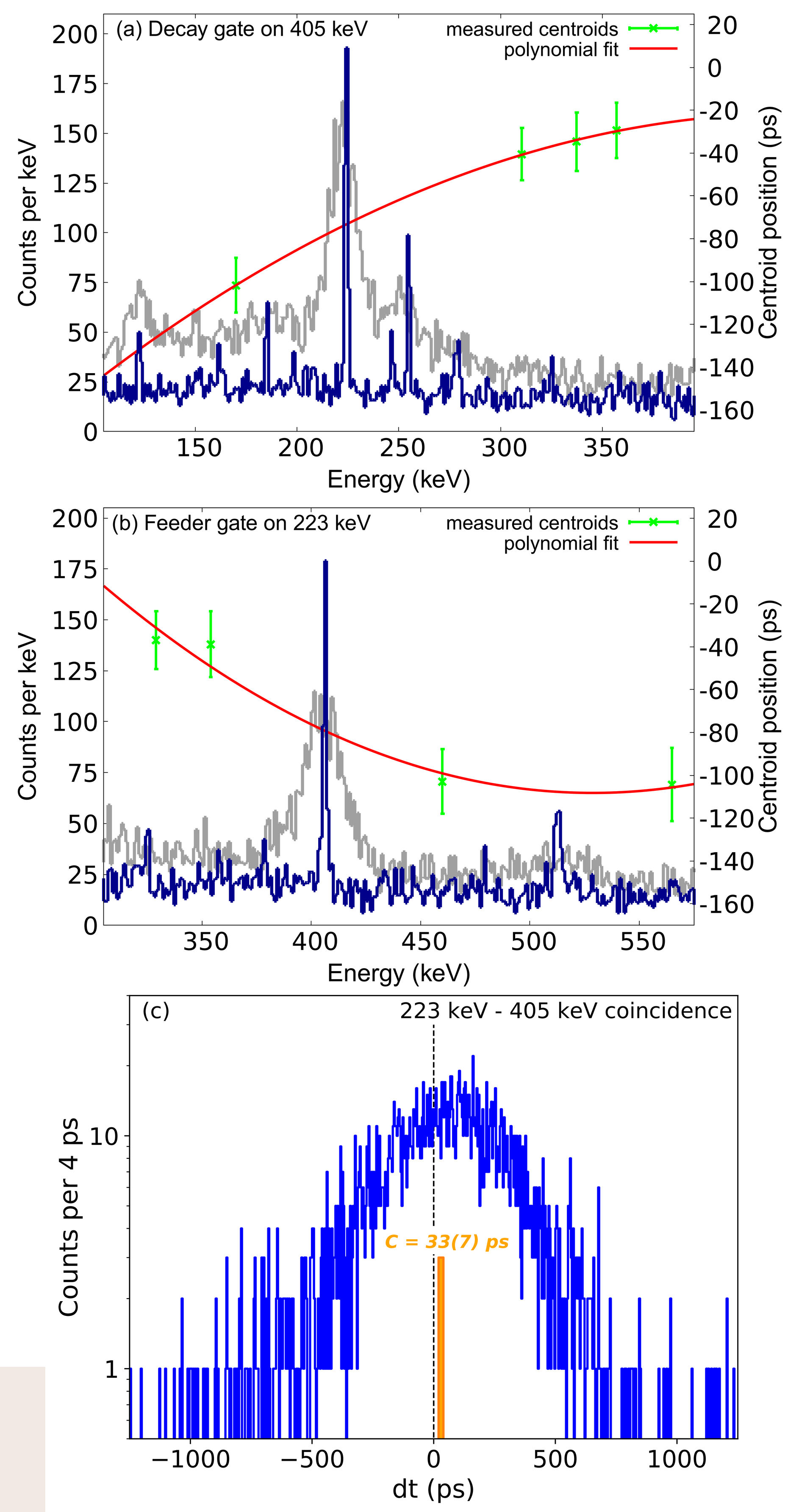
$LaBr_3$(Ce) detectors are essential due to their good time resolution.

The **Centroid Shift method** [8,9] is based on the difference between the measured centroid of the time-difference distribution to the **prompt centroid position**, calibrated applying an ^{152}Eu source:

$$\tau = C(E_f, E_d) - C^P(E_f, E_d)$$

From our data set the lifetime of all low-lying yrast states in 212Po can be determined applying the *Centroid shift method* and *Slope method*:

State	This work	Literature [1]
2_1^+	16(13) ps	20.5(26) ps
4_1^+	**100(14) ps**	-
6_1^+	1.66(28) ns	1.1(3) ns
8_1^+	20.8(17) ns	21.1(4) ns

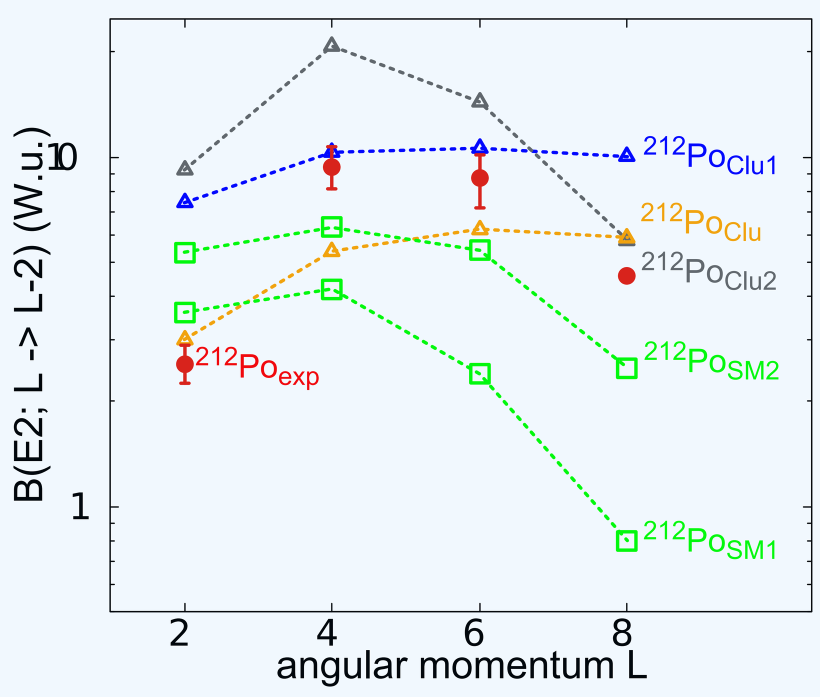


Structure discussion of ^{212}Po

The newly derived lifetime of the 4_1^+ state completes the knowledge of the experimental B(E2; L → L − 2) values of the low-lying yrast states.

Shell model approaches (SM1 [3], SM2 [4]) cannot describe the whole systematics of the B(E2) values.

The trend of experimental B(E2) values are better described in the framework of an α-clustering model (Clu this work, Clu1 [2], Clu2 [5]) → α-cluster components play an important role in the structures of these states.



Reduced transition probabilities for the low-lying yrast states.

Outlook

To fully prove the impact of the α-cluster components more experimental information on the α-branchings and the static electromagnetic moments of the yrast states in ^{212}Po is needed.

References

[1] K. Auranen et al., Nuclear Data Sheets 168 (2020) [2] F. Hoyer et al., Phys. Rev. C 50, 2631 (1994) [3] H. Naïdja, Phys. Rev. C 103, 054303 (2021) [4] D. Kocheva et al., Phys. Rev. C 96, 044305 (2017) [5] D. S. Delion et al., Phys. Rev. C 85, 064306 (2012) [6] D. Bucurescu et al., Nucl. Instr. Meth. A 837, 1-10 (2016) [7] T. Beck et al., Nucl. Instr. Meth. A 951, 163090 (2020) [8] H. Mach et al., Nucl. Instr. Meth. A 280, 49-72 (1989) [9] J.-M. Régis et al., Nucl. Instr. Meth. A 622, 83-92 (2010)