Measurements of transition probabilities with JUROGAM and MINIBALL

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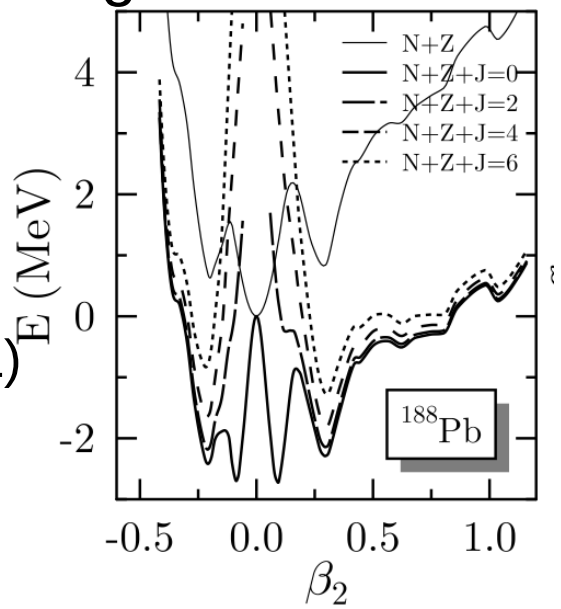
Outline

- Physics background
- Lifetime measurements at JUROGAM
- Coulomb excitation studies at MINIBALL

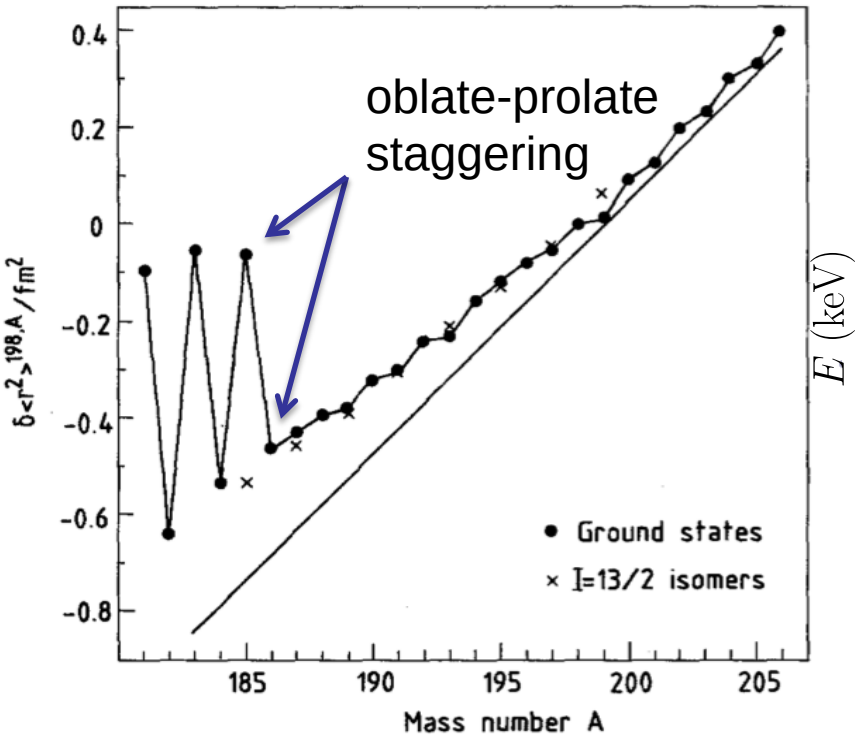
Shape coexistence around Z=82 and N=104

- Different shapes of an atomic nucleus (spherical, prolate, oblate) coexist at similar excitation energies.
- Unique laboratory to study shape coexistence as complementary studies can be carried out:
  - Accessible by fusion-evaporation reactions and tagging techniques (JYFL) → lifetime (plunger) measurements.
  - Post-accelerated rare isotope ISOL beams available (ISOLDE) → Coulomb excitation.

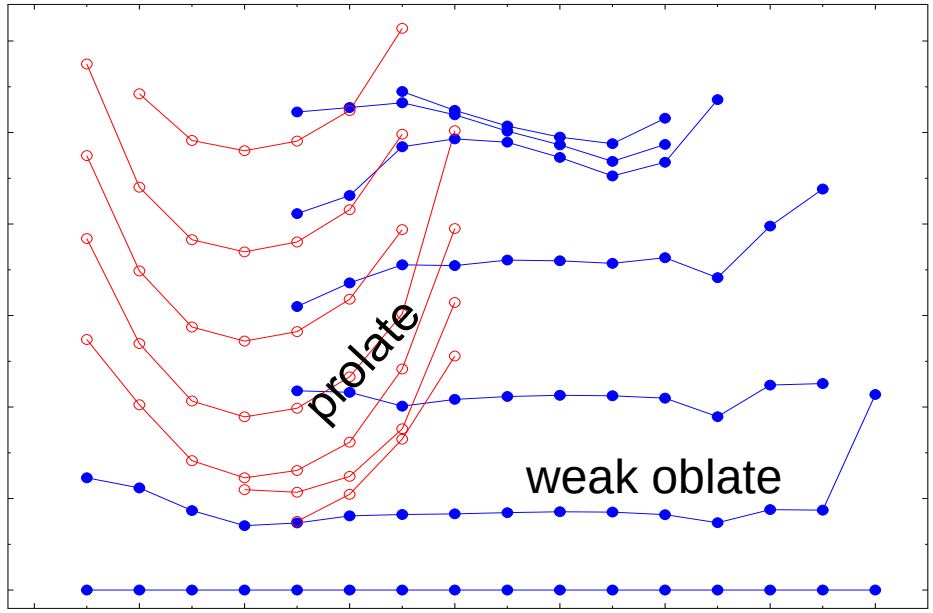


M. Bender and P.-H. Heenen
J. Phys. G 31, S1367 (2005)

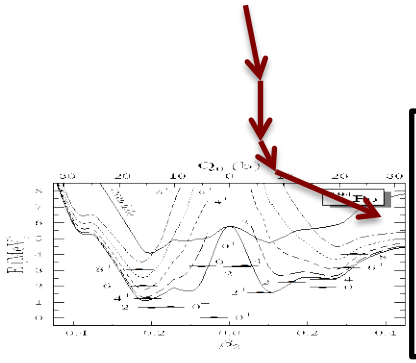
Neutron-deficient Hg nuclei



G. Ulm et al., Z. Phys. A 325, 247 (1986)



Experimental probes of shape coexistence

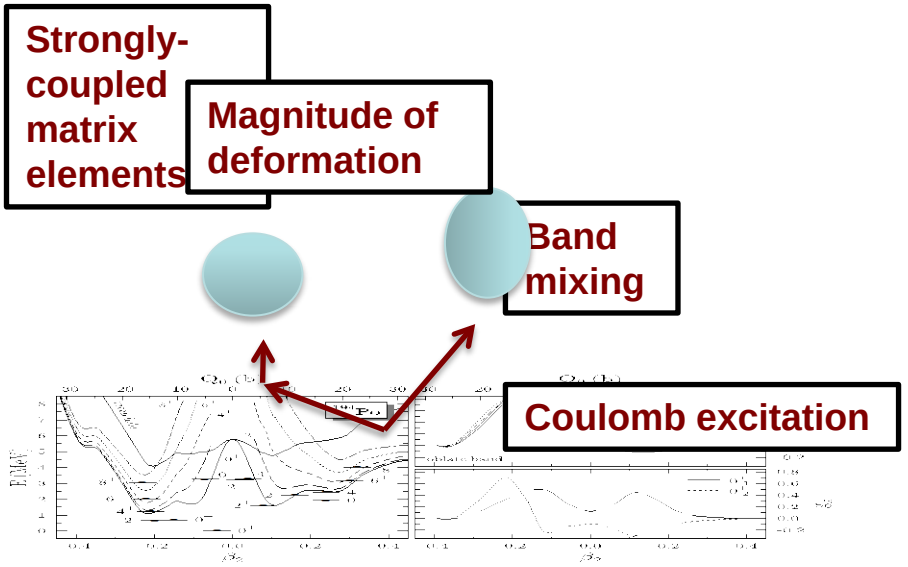


Mean lifetime $\tau \rightarrow B(E2)$ value

- **Magnitude of the transition quadrupole moment**
- **Magnitude of deformation**

Configuration mixing calculations of angular momentum projected mean-field states,
T. Grahn et al. Nucl Phys. A 801, 83 (2008)

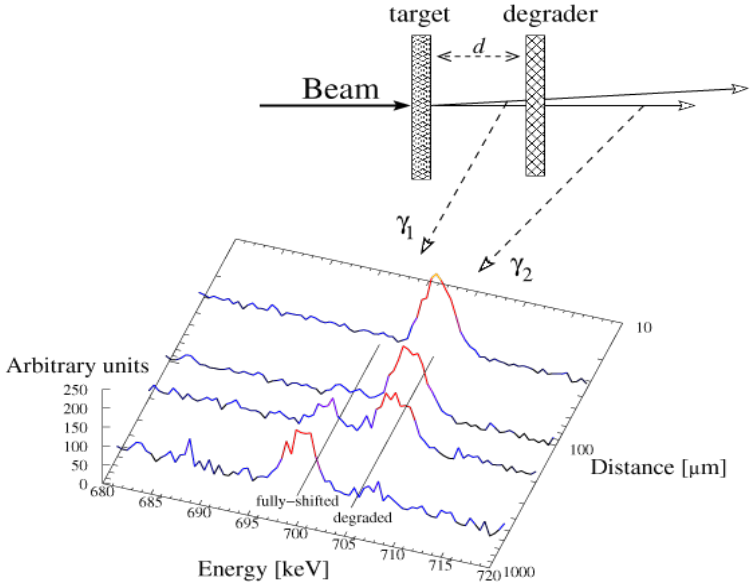
Experimental probes of shape coexistence



Configuration mixing calculations of angular momentum projected mean-field states,
T. Grahn et al. Nucl Phys. A 801, 83 (2008)

Lifetime measurements in at JYFL

- Recoil distance Doppler-shift (RDDS) lifetime measurements with JUROGAM + RITU.
- Complementary to the Coulomb excitation measurements, provide further constraints in the analysis of such data.



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Lifetime measurements in at JYFL

Difficulties

Use of the degrader foil:

- JUROGAM II Ge-detector background rate increases.
- With a 1 mg/cm^2 Mg foil, RITU transmission efficiency cut by a factor of 2/3.
- Doppler-shift difference rather low: v/c = 4% $\rightarrow$ v/c =3%.

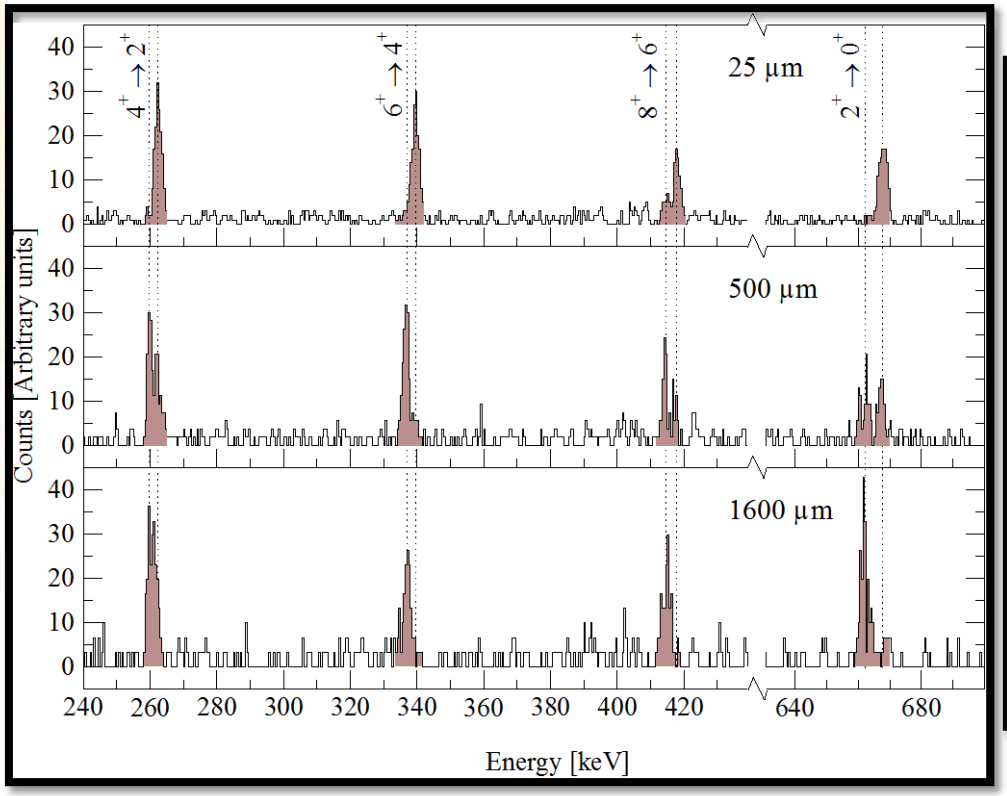
Suitable θ:

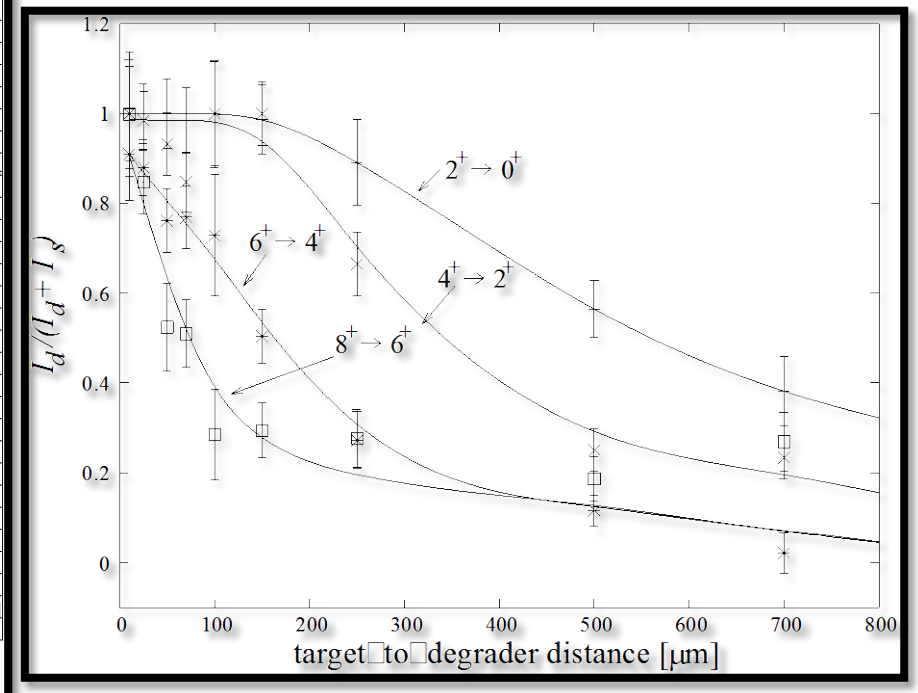
- Only 15 of JUROGAM II Ge-detectors can be used; 5 at 158° and 10 at 134°.
- Ge efficiency reduced significantly.

Reaction cross section & residue:

- Measurements down to 50 μb level carried out.
- The nucleus of interest has to have a sufficient p- or α-decay branch for RDT.
- If the exit channel of the reaction is dominant, recoil gating will provide a rather clean tag.

Recoil-decay tagged lifetime measurements in ^{186}Pb





T. Grahn et al.,
Phys. Rev. Lett. 97, 062501 (2006),
Nucl. Phys. A 801, 83 (2008)

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RDDS measurements in ^{186,188}Pb

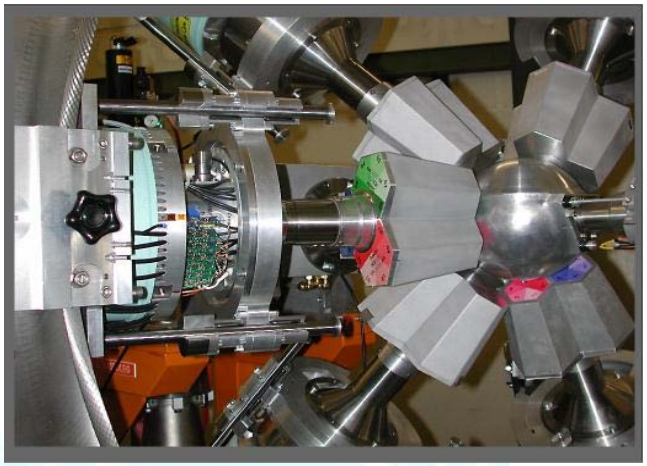
- Verified the collectivity and deformation of prolate yrast band in the neutron-deficient Pb nuclei.
- Configuration mixing of three distinct shapes: spherical ground state, prolate and oblate structures at low excitation energy.
- **Prolate** in **Pb: $|\beta_2| = 0.29(5)$**
- Initiated campaigns of lifetime measurements at JYFL, most notably systematic studies of lifetimes and collectivity near ***Z*=82** and ***N*=104**.

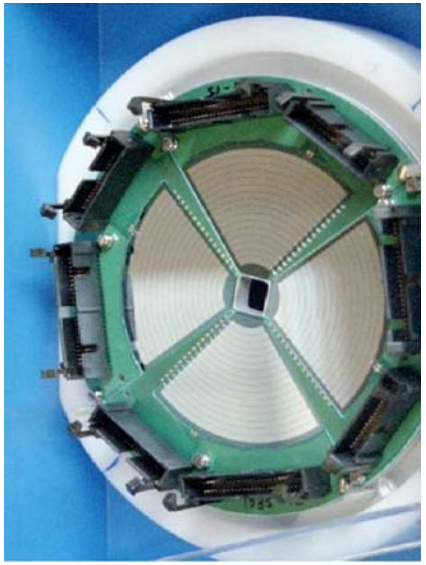
Even-mass $^{188\text{-}192}$Pb nuclei

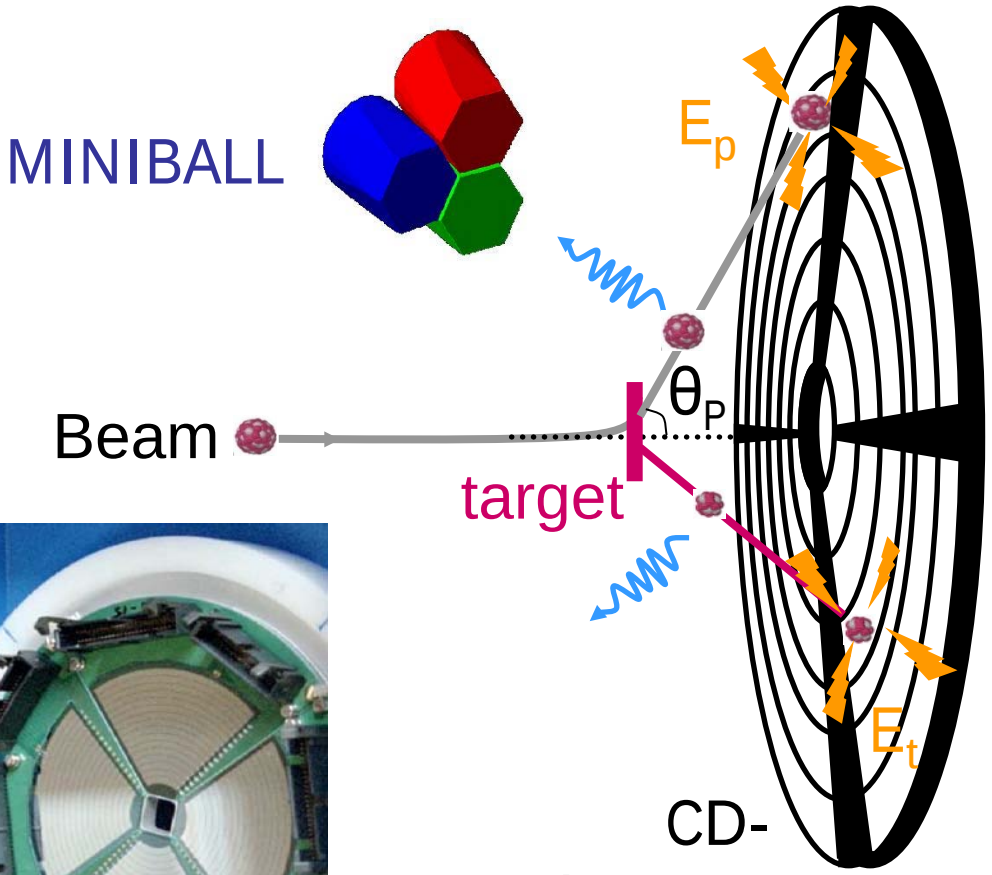
- Complementary measurements of transition probabilities between the coexisting prolate, oblate and spherical structures:
  - Lifetime measurements of excited states in ^{186,188}Pb using the RDDS method at JYFL (Phys. Rev. Lett. 97, 062501 (2006).
  - Coulomb excitation measurements of ^{188,190,192}Pb at REX-ISOLDE (IS494, Spokespersons: T. Grahn & J. Pakarinen).
- Aim to extract a complete set of matrix elements.

MINIBALL spectrometer

- MINIBALL γ-ray spectrometer (8 triple Ge clusters, six-fold segmented) surrounding a target.
- CD Si detector for recoil detection (16 annular strips).







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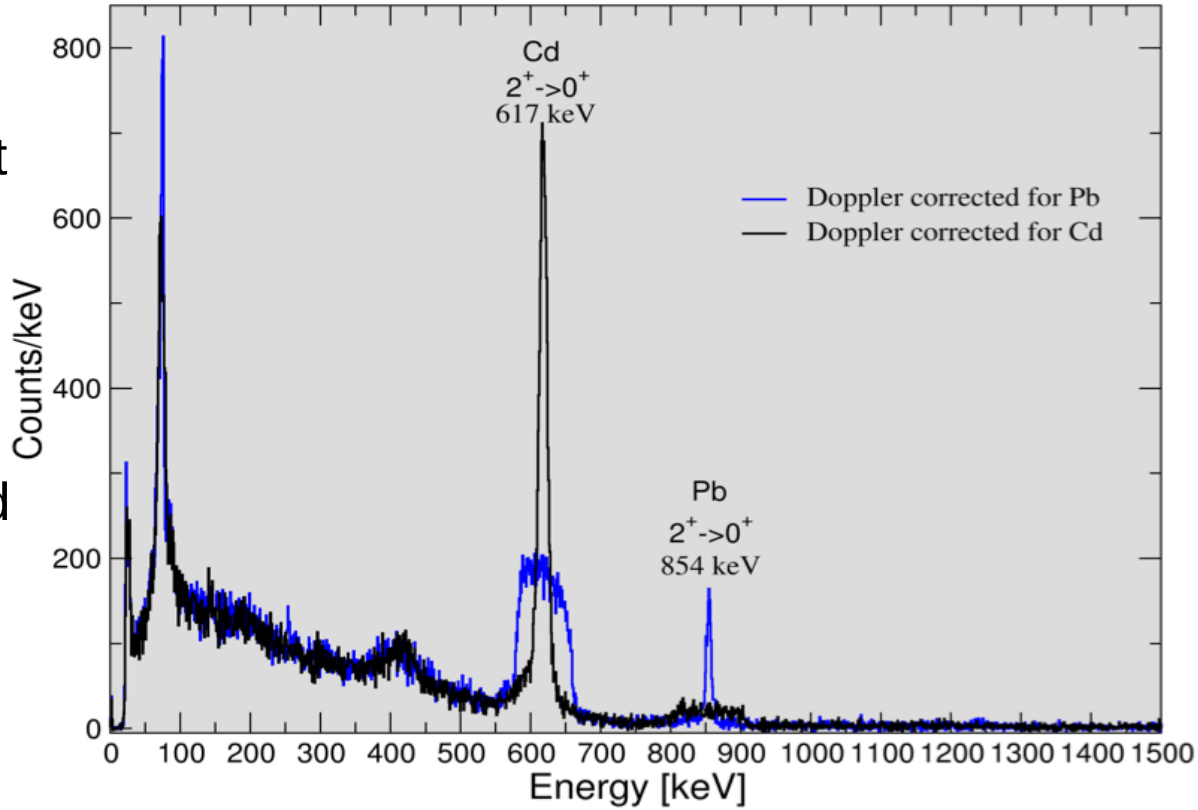
IS494, ^{192}Pb, August 2010

- Coulomb excitation of ^{192}Pb completed August 2010
- ^{188,190}Pb completed in June 2011.
- Additional Coulomb excitation data collected on ^{194,196,198}Pb nuclei.



2.84 MeV/u ^{192}Pb beam on 2 mg/cm^2 thick ^{112}Cd target.
Beam intensity: 5×10^5 pps.

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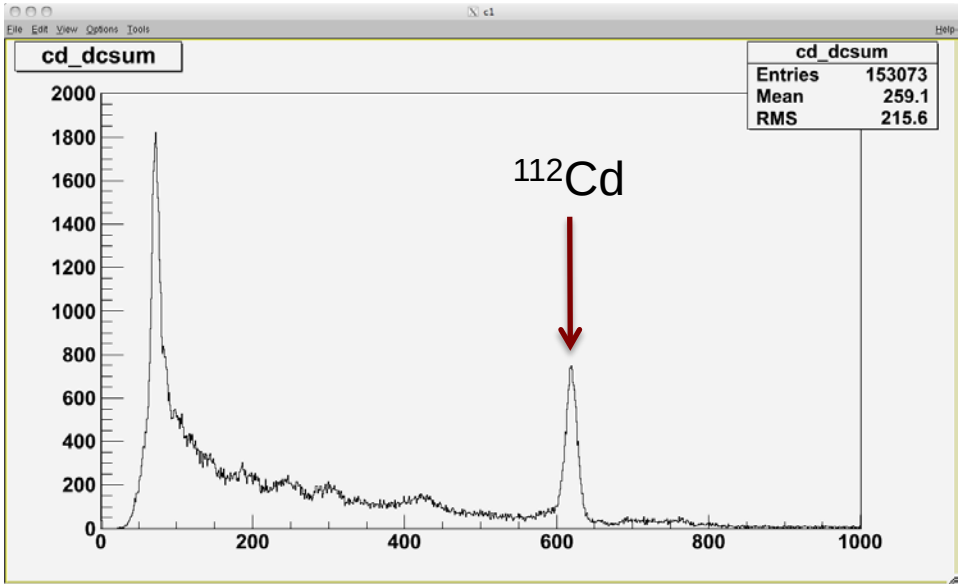
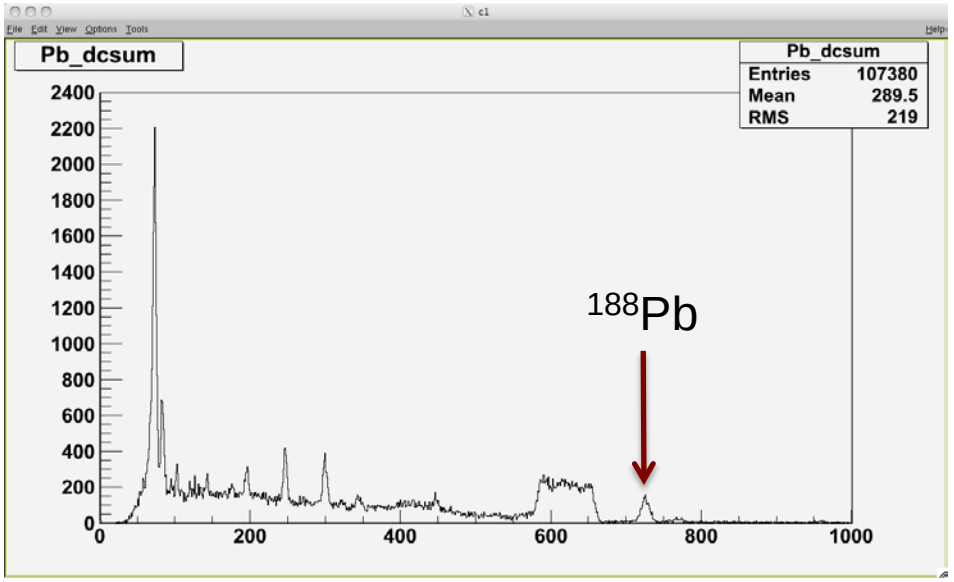
IS494, ^{188}Pb, June 2011



Doppler correction for ^{112}Cd



Doppler correction for ^{188}Pb

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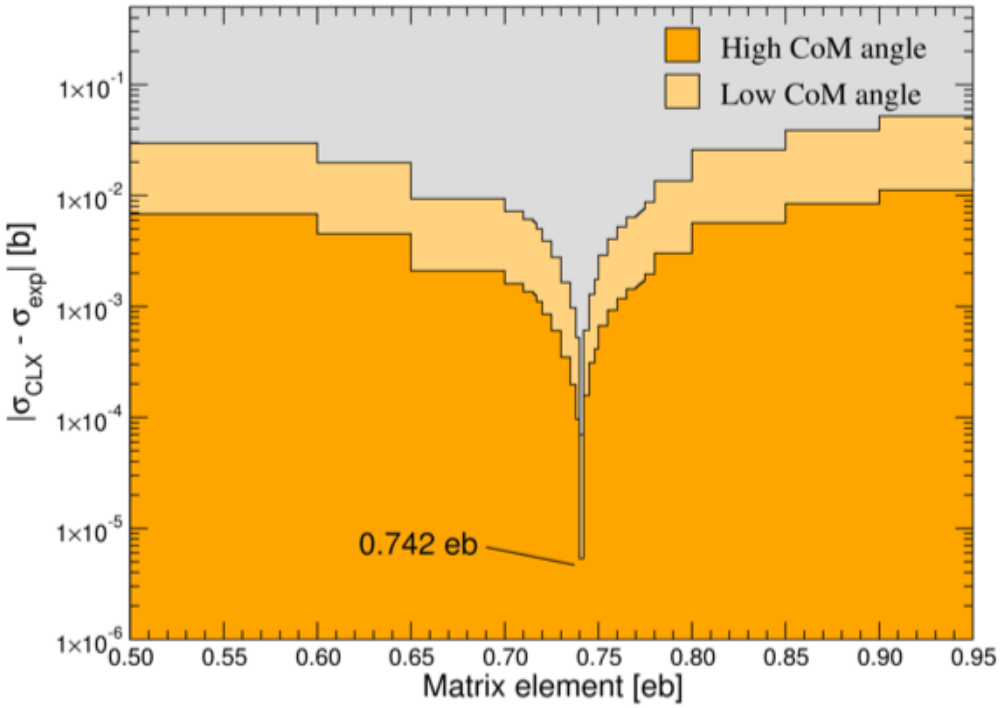
^{192}Pb

- Matrix element ~0.742 *e*b ⇔*B*(*E*2) ~17 W.u.
- Higher *B*(*E*2) than at the mid shell (c.f. 6(2) W.u. in ^{186}Pb)



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Summary

- Lively research programme of complementary studies at CERN-ISOLDE and JYFL.
- Lifetime measurements in neutron mid-shell Pt, Hg, Au, Pb and Po nuclei at JYFL and ANL (talk by M. Hackstein).
- Coulomb excitation of re-accelerated neutron-deficient Hg, Pb, Po and Rn nuclei at REX-ISOLDE & MINIBALL.
- Studies of transition probabilities will provide an extensive set of experimental matrix elements → stringent constraints for future theory development.