RDDS measurements at RITU and prospects at HIE-ISOLDE

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Outline

- Tagging instrumentation at JYFL
- Lifetime measurements utilising selective tagging methods at JYFL
- Plunger device at MINIBALL
- Plunger device at HIE-ISOLDE spectrometer?

BACKGROUND AND MOTIVATION

- **Shape coexistence in the neutron-deficient Pb region**: large body of spectroscopic information obtained with stable beams but the knowledge of transition probabilities was missing.

  → **Couple the Köln plunger device to JUROGAM + RITU** at the University of Jyväskylä (JYFL).

- ^{186}Pb & ^{194}Po: First **Recoil Distance Doppler-Shift** (RDDS) lifetime measurements employing the RDT technique. Improved lifetime information on ^{188}Pb using the recoil-gating method (PRL 97, 062501 (2006) & NPA 801, 83 (2008)).
- Demonstrated that RDDS lifetime measurements are possible for such exotic species.

  → Ongoing programme to study lifetimes in nuclei far from stability.

- RDDS measurements in the light Pb region are complementary to the Coulomb excitation measurements carried out at REX-ISOLDE.

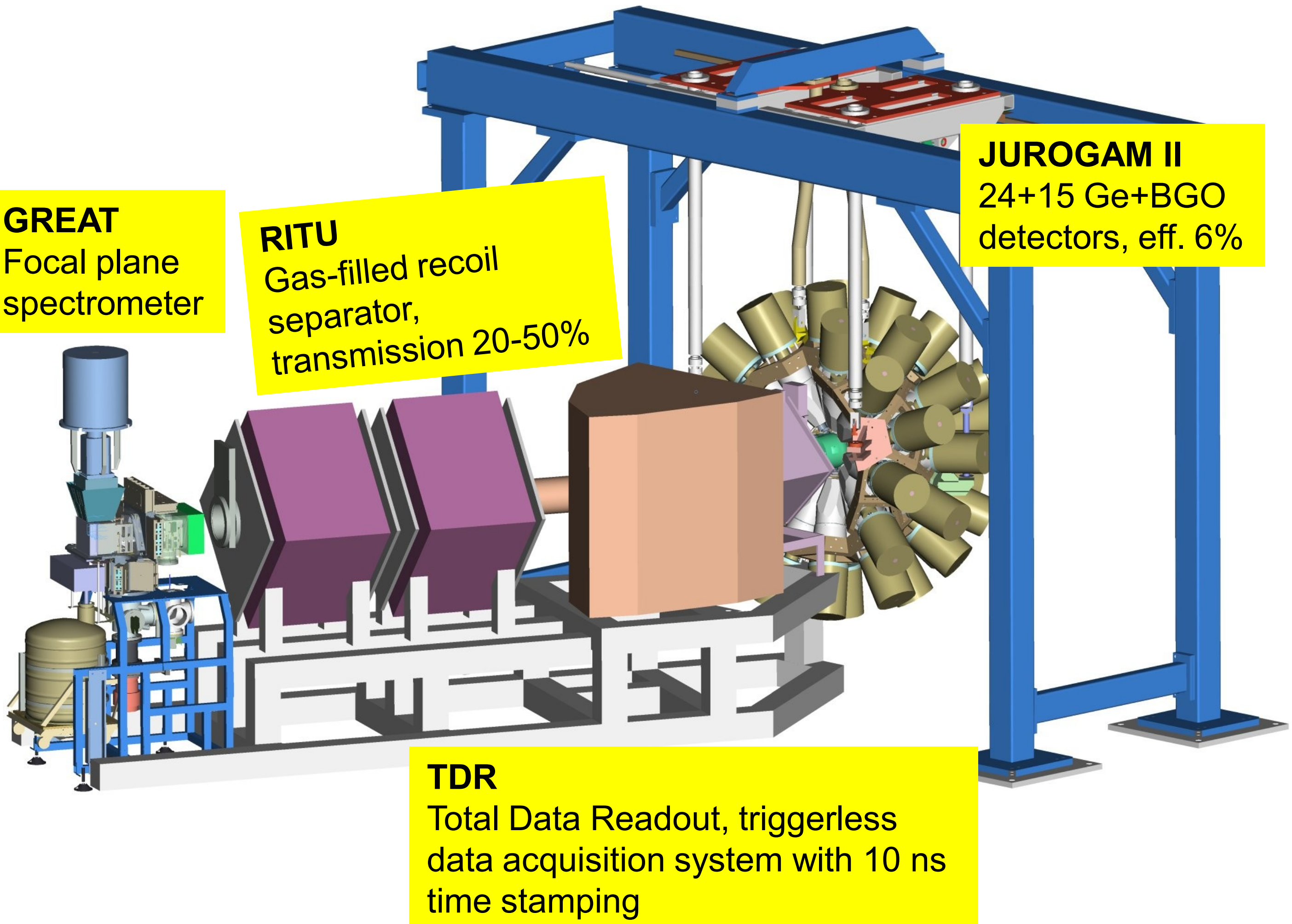
  →State lifetimes set constraints in the analysis of Coulomb excitation data.

Examples of physics cases

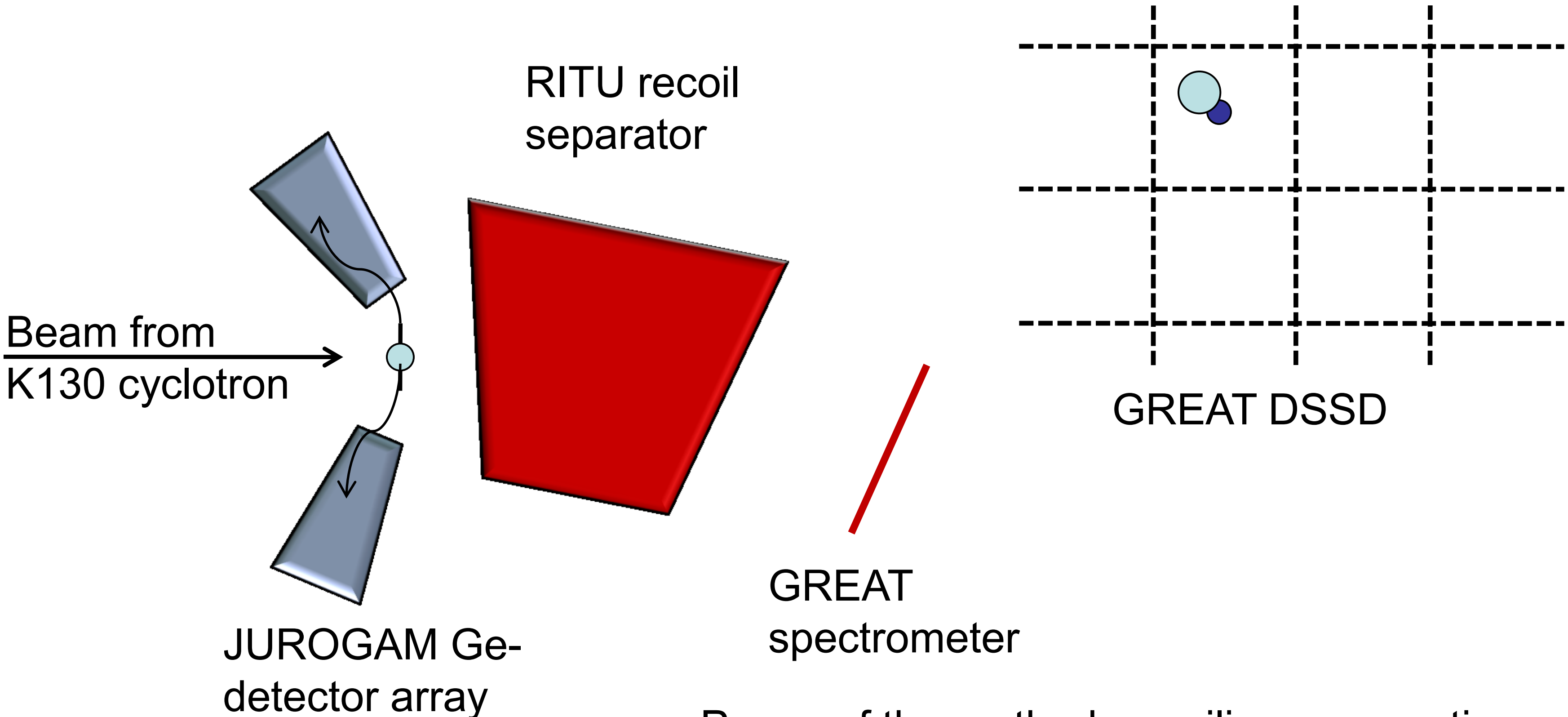
- Shape coexistence: $^{186,188}Pb$, $^{194\text{-}196}Po$, $^{180,182}Hg$, ^{175}Au, $^{174,175}Pt$, ^{182}Pt.
- Transition between deformed and spherical structures: $^{166\text{-}168}Os$.
- Collectivity and shell evolution above ^{100}Sn: $^{108,110}Te$, ^{109}I.
- Recoil-isomer tagging, e.g. ^{144}Ho

The RITU separator renders it possible to access very neutron-deficient nuclei and RDT method results to a very clean γ-ray spectrum for RDDS studies.

Tagging instrumentation at JYFL

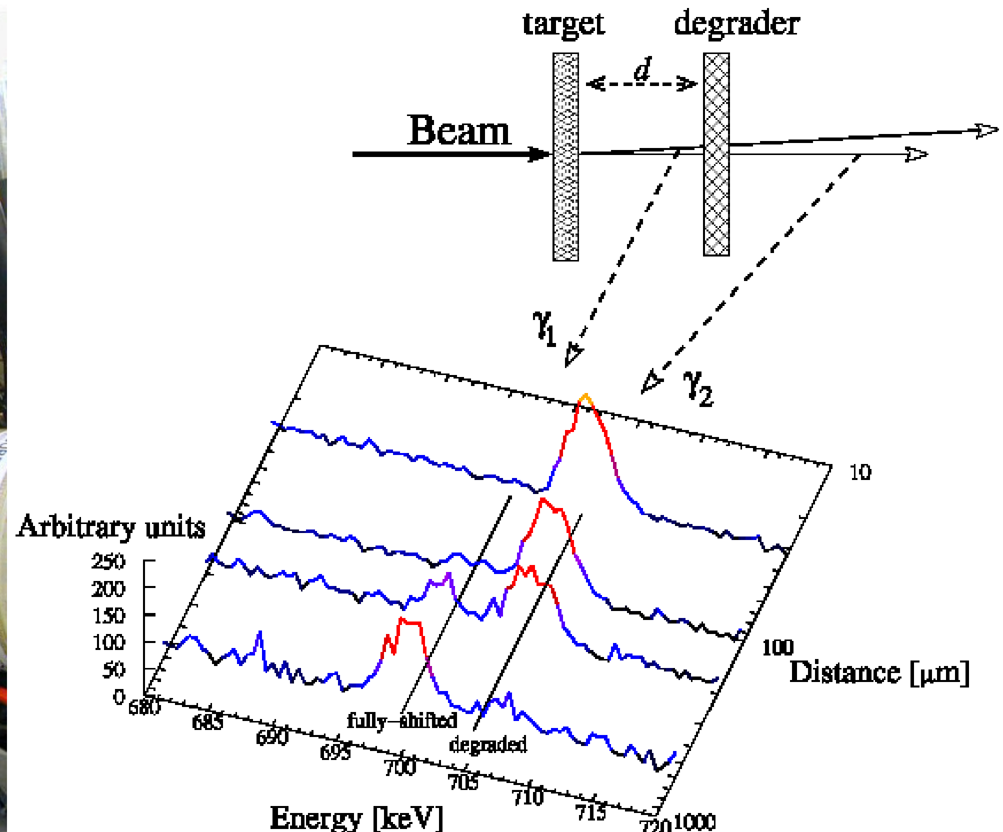


Recoil-Decay Tagging (RDT) method



Power of the method: recoiling evaporation residue and its subsequent characteristic decay observed ⇒**unique tag for the prompt radiation.**

RDDS lifetime measurements at JYFL

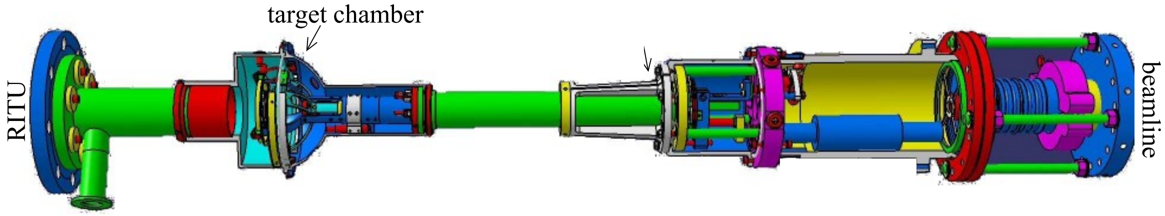


First ever Recoil Distance Doppler-Shift (RDDS) lifetime measurements utilising a gas-filled recoil separator and the RDT technique → a special plunger device with a degrader foil designed by the University of Köln.

RDDS lifetime measurements at JYFL

The Köln plunger device at RITU:

- \`Standard´ stopper foil replaced by a degrader foil in order to allow evaporation residues to enter RITU.
- Moveable target allows the target-to-degrader distance to be varied.
- Motors operate in vacuum, therefore it has to be isolated from the He gas of RITU ⇒ C window.



RDDS lifetime measurements at JYFL

Difficulties/limitations

Use of the degrader foil:

- JUROGAM II Ge-detector counting 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% → 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.

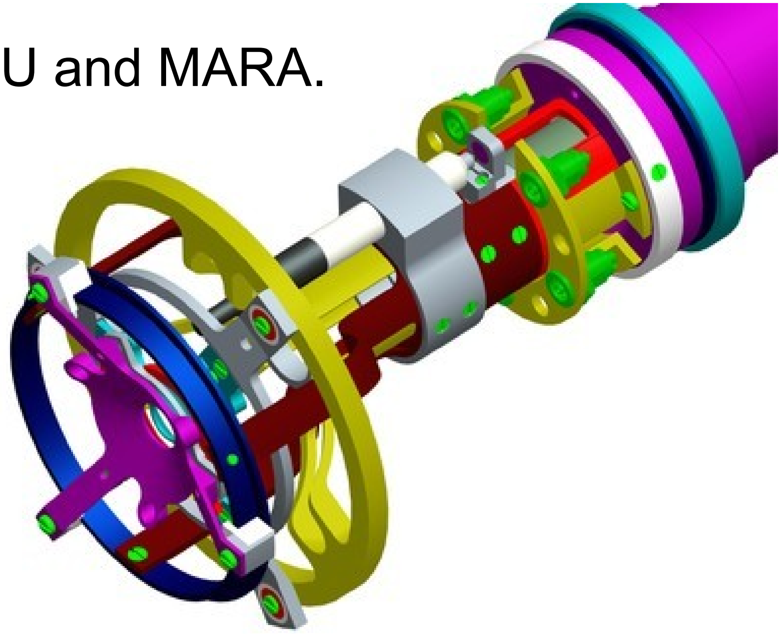
Reaction cross section & residue:

- 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.

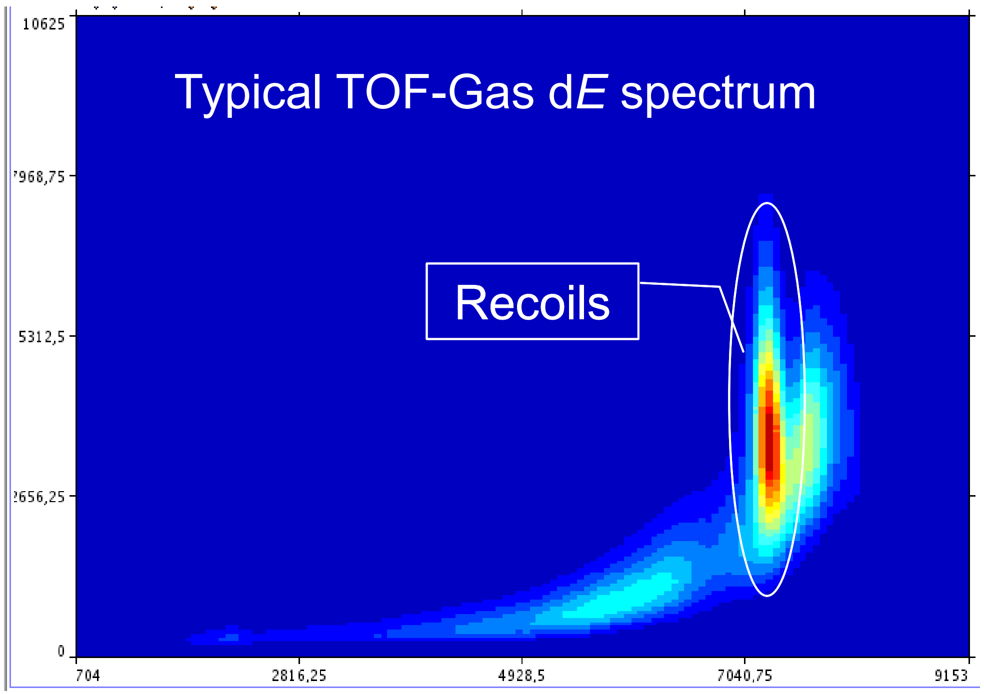
RDDS lifetime measurements at JYFL

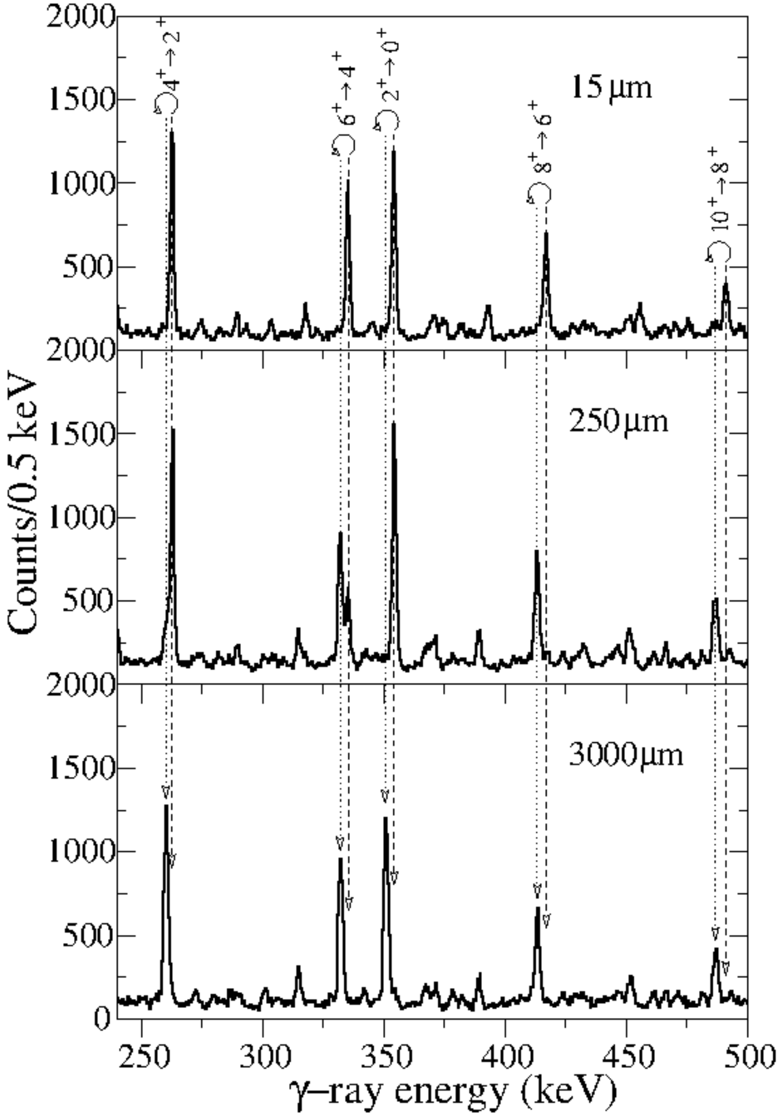
The DPUNS plunger device

- Based on the Köln plunger design, constructed by University of Manchester.
- Can operate in He of RITU ⇒ differential pumping.
- To be completed in 2011.
- Dedicated instrument for RITU and MARA.



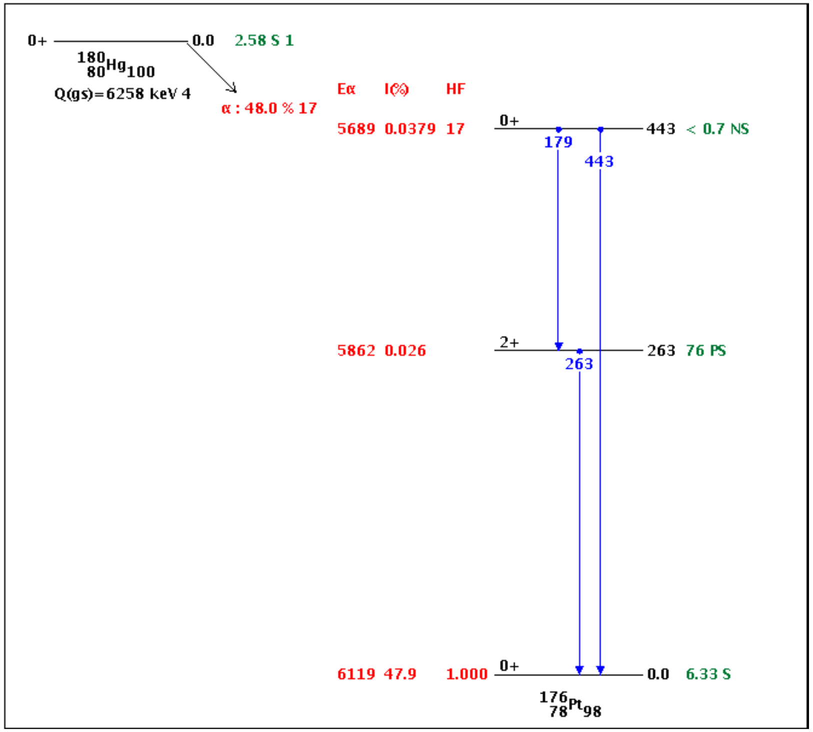
Lifetimes in ^{180,182}Hg

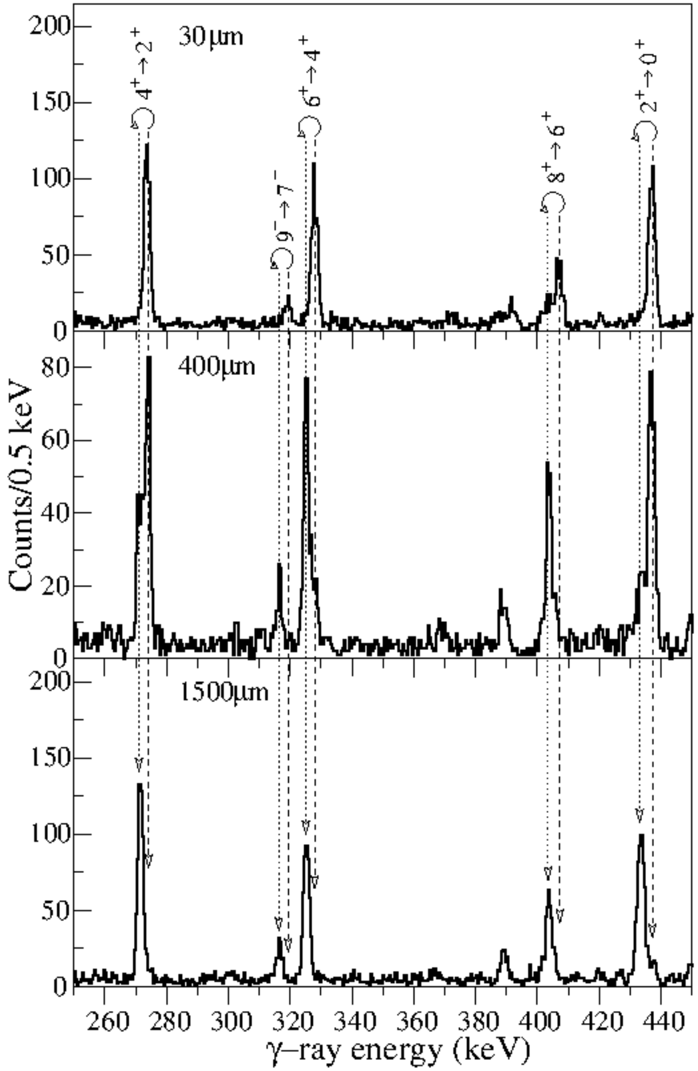




^{96}Mo(^{88}Sr,2n)^{182}Hg, *E*=310 MeV. Recoil-gated projections of γγ-coincidence spectra.

Lifetimes in ^{180,182}Hg



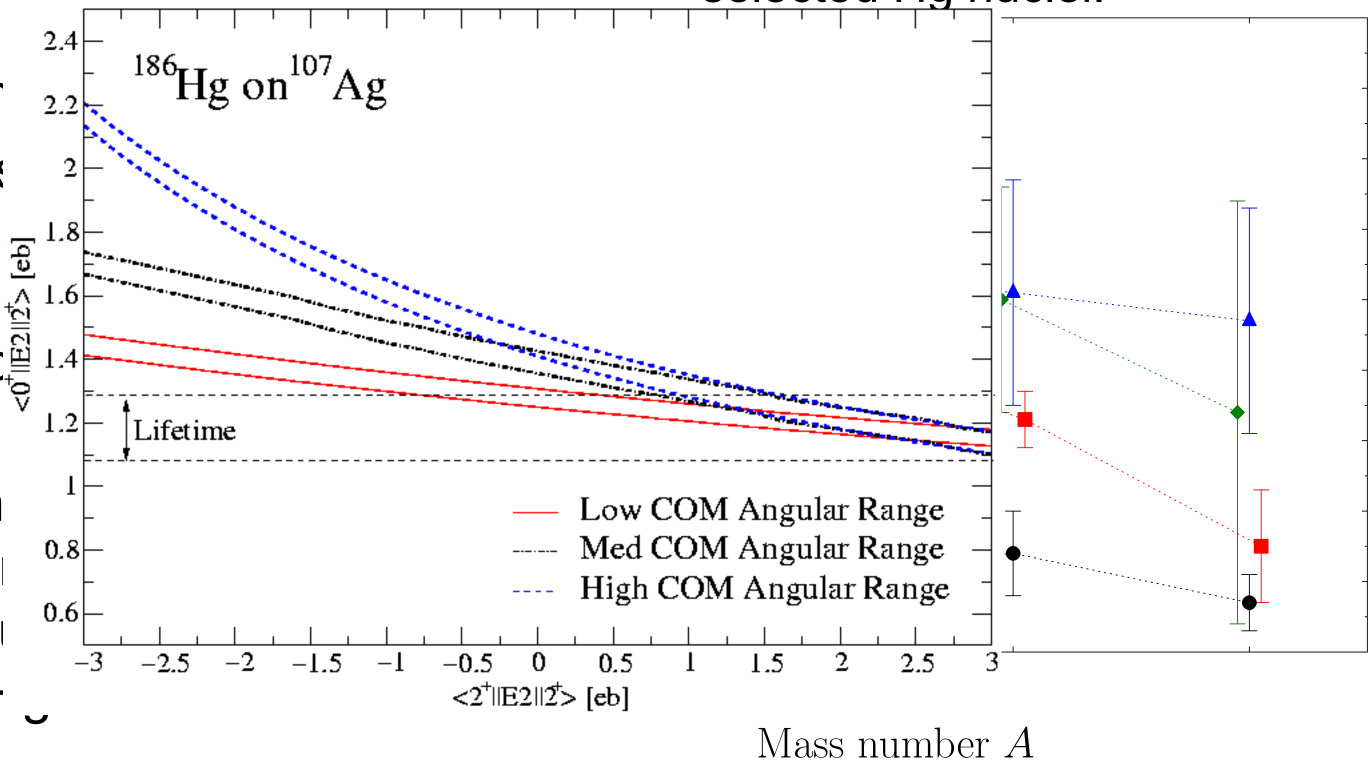


^{94}Mo(^{88}Sr,2n)^{182}Hg, *E*=300 MeV. RDT singles γ-ray spectra, tagged with ^{180}Hg α decay, at three target-to-degrader distances.

Lifetimes in ^{180,182}Hg

- High collectivity of the states with $I^{\pi} \geq 4$ indicate thei deformed ch
- The results shape coexi weak oblate intruding pro structures
- Complemen measureme excitation st 182,184,186,188H ISOLDE

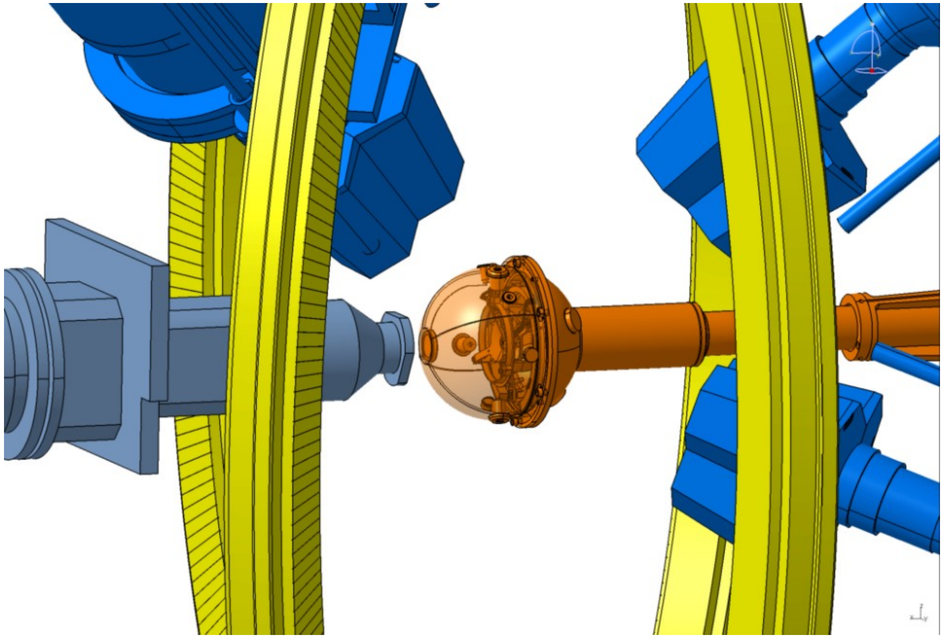
Transition quadrupole moments of selected Hg nuclei.



T. Grahn et al., PRC 80, 014324 (2009)

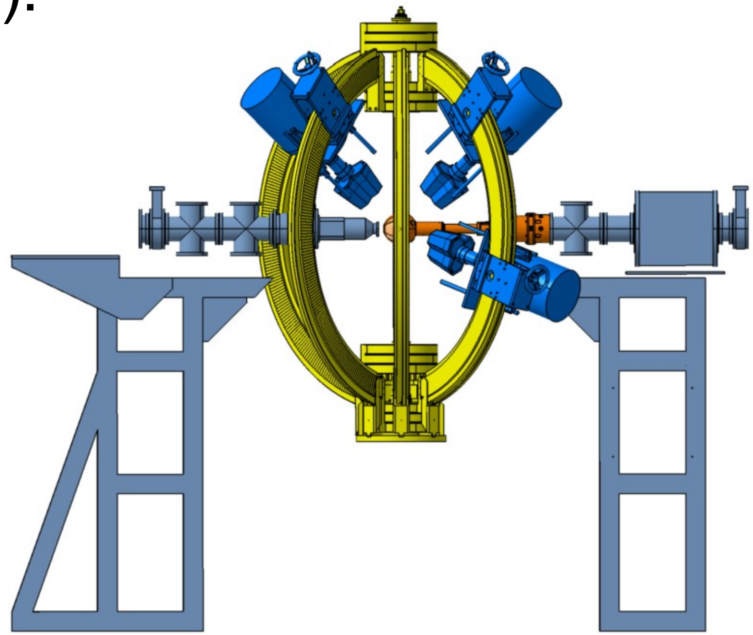
Plunger device at MINIBALL

- Project jointly managed by Demokritos Athens and IKP Köln.
- The plunger device is based on the Köln design.
- The design process is ongoing.



Plunger device at MINIBALL

- Target chamber incorporates the plunger device upstream and the CD Si detector downstream.
- Experience gained in JYFL experiments with the `CoulEx plunger' (Köln plunger device + particle detector array).



Plunger device at HIE-ISOLDE spectrometer?

- HIE-ISOLDE spectrometer LoI: Several physics cases and methodologies:
  - Transfer reactions
  - Deep inelastic reactions
  - Fusion-evaporation reactions
- Several experimental scenarios for the plunger device could be envisaged.
- Plunger device is relatively easy to couple with a separator.

Plunger device at HIE-ISOLDE spectrometer?

- Deep inelastic & transfer reactions
  - Reaction kinematics could be problematic.
  - However, such studies have been carried out at CLARA-PRISMA, LNL (see e.g. D. Mengoni et al., EPJA 42, 387 (2009)).
- Fusion-evaporation reactions
  - Difficulties: low beam intensity, low cross section.
  - Beam intensity at JYFL usually 1 pnA ⇔ ~10^8 pps, cross sections down to 50 μb.
  - Similar intensities could be achieved at HIE-ISOLDE, due to the projected intensity increase, for radioactive beams `not so far from stability´.

Plunger device at HIE-ISOLDE spectrometer?

- Would provide a complimentary method to Coulomb excitation in measurements of transition probabilities.
- Not sensitive to reaction mechanism and target excitations.
- May provide access to measurements of transition probabilities in regions of the nuclear chart otherwise inaccessibly with Coulomb excitation (deep-inelastic/fusion-evaporation reactions).