Measurement of Th-229 low lying isomeric state with MRTOF+TES system at RIKEN-RIBF

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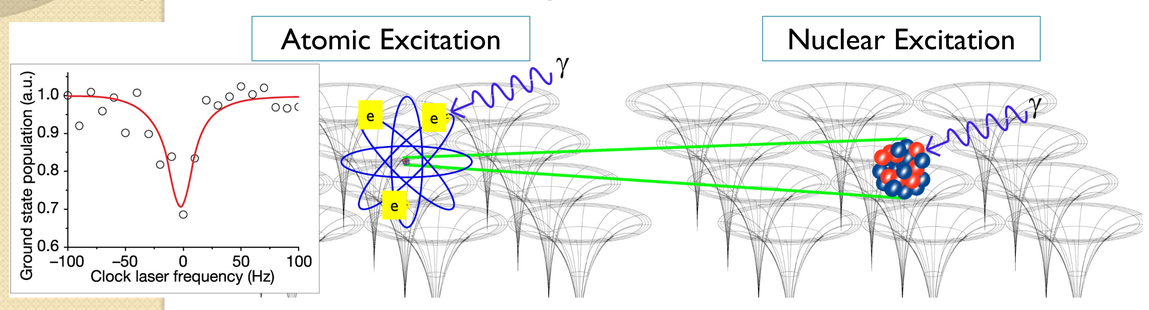
Physics motivation

Th-229 is famous nucleus as the unique candidate of nucleus which can be utilized for realizing nuclear clock. Historically Th-229 is expected to have very low lying isomeric state of less than 10 eV. Existence of 10 eV excited state means the nucleus can be excited by the 124 nm UV LASER beam. Once the energy level of such isomeric state can be determined precisely by the order of 0.1~0.01 eV, it is realistic to measure the excited state of Th-229 by using LASER Comm technique.



Previously large amount of experimental efforts were made to search for such low lying isomeric state of Th-229 for a long time. Finally, Wense et. al, succeeded to measure the internal conversion electron coming from the Th-229 isomeric state.

Th-229m experiment at RI beam facility

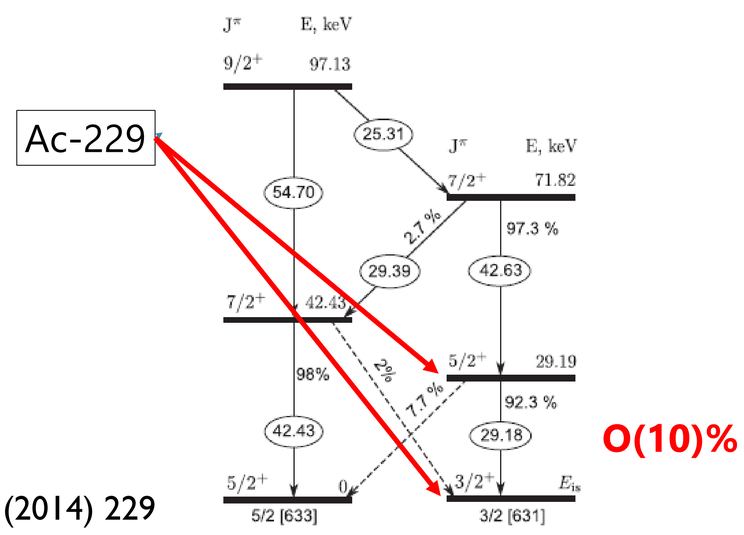
We are planning following measurements with online RI beam

- Precise measurement of IC electron energy w/ optical TES.
  - Implant charged Th-229m, which becomes neutral Th-229m by getting electron from around → decay to ground state after 7μs.
- Precise measurement of decay gamma from Th-229m→ground.
  - Charged Th-229m should be kept for seeing this transition.
  - Energy of photon can be measured precisely with spectroscopic method.
- Precise measurement of two types of transition: 29.19keV→8eV and 29.19keV→ground
  - Easier in terms of experimental setup.
  - Application of X-ray TES, while high resolution is required.

Th-229m from Ac-229 beta-decay

Advantages of the coincidence measurement with electrons emitted from Ac-229 beta-decay (Q = 1170 keV):

1. Background rejection with the detection of beta-decay elections.
2. Ac-229 is expected to feed Th-229m with high branching ratio of several tens of percent.
   - the Nilsson state of Ac-229 is the same as that of Th-229m.
   - much higher than 2% when using the U-233 source alpha-decay.



O(10)%

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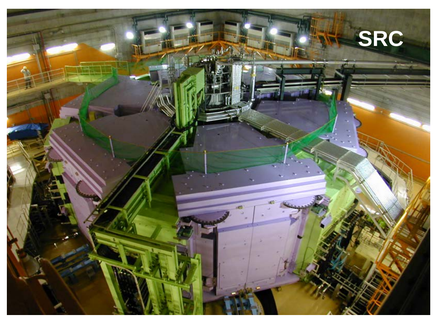
RIKEN-RIBF for Th-229/Ac-229 production

The RIKEN-RIBF accelerators allow to provide the world's most intense RI beams.

- High-energy and intense primary beams accelerated by a superconducting ring cyclotron (SRC)
- State-of-art in-flight fragment separator: BigRIPS
  - Large ion-optical acceptances and a two-stage structure

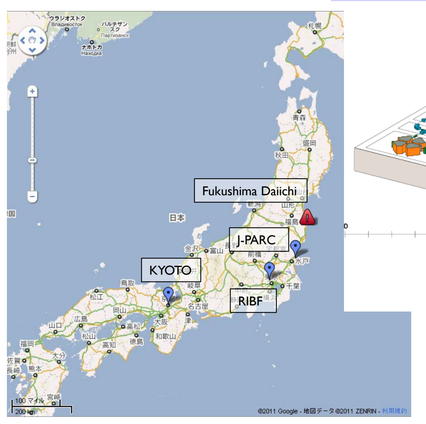
World's First and Strongest Superconducting Ring Cyclotron

400 MeV/u Light-ion beam
345 MeV/u Uranium beam

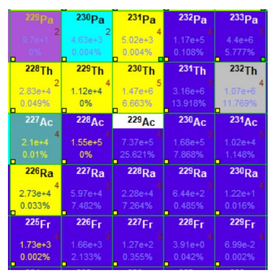


World's Largest Acceptance Superconducting RI beam Separator

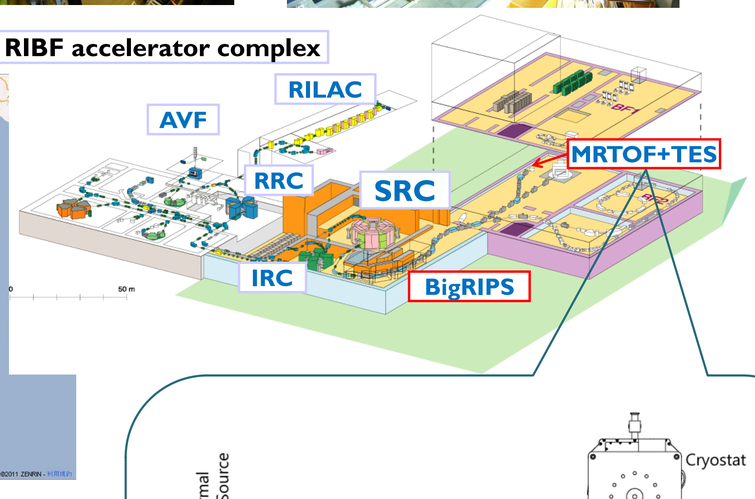
~250-300 MeV/nucleon RI beam

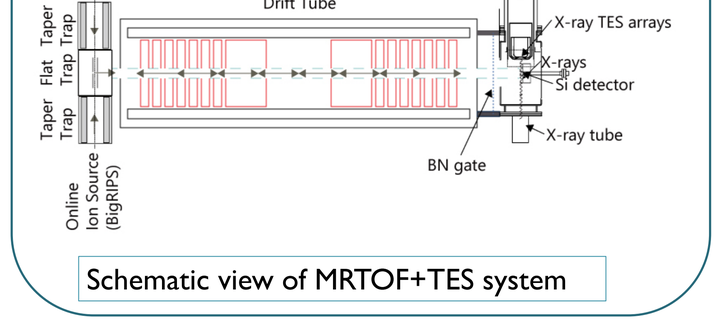


Purified Ac-229/Th-229 isotopes are doped into optical TES/Si



RIBF accelerator complex





Schematic view of MRTOF+TES system

- Primary U beam, 40pnA → 740kHz Ac-229, purity 25% by BigRIPS

MRTOF for isobar separation

Multi-reflection Time-Of-Flight (MRTOF): An electrostatic ion trap, wherein low-energy ions (with kinetic energy <5keV/q) reflect between a pair of energy isochronous, grid-free, electrostatic mirrors to produce an extremely long flight path.

- Resolving power: Rm~200000
- MRTOF gas catcher kick the ions every 10ms.
- In 10ms, 7400 Ac-229 ions are coming in MRTOF gas catcher
  - 30k total ions every 10ms.

A	Z	N	Mass (μu)	Element	Δm(vsTh)[ppm]	Δtof(vs Th) [ppm]	ToF-Tof(Th) [ns]
229	86	143	229042257.3	Rn	45.83	22.91	229.13
229	87	142	229038291.5	Fr	28.51	14.26	142.56
229	88	141	229034956.7	Ra	13.95	6.98	69.76
229	89	140	229032947	Ac	5.18	2.59	25.88
229	90	139	229031761.4	Th	0	0	0.00
229	91	138	229032095.7	Pa	1.46	0.73	7.30
229	92	137	229033505.9	U	7.62	3.81	38.08
229	93	136	229036264	Np	19.66	9.83	98.29
229	94	135	229040145.8	Pu	36.61	18.30	183.04

→ Precise measurement of Th-229 low lying state with TES under background less condition.