JUSEIPEN Workshop @ LBNL

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DECAY GAMMA EXPERIMENTS

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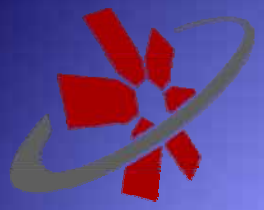
Outline

- Status of RIBF
  - Facility
  - Location of Decay Experiment
- Status of Decay-Spectroscopy
  - Double-Sided-Silicon-Detector (DSSD)
  - Readout Electronics
  - Ge detectors (Clover)
  - Super-segmented beta-counting system
- Proposals and Future
  - Decay Spectroscopy Experiments at RIBF
  - Below A < 100
  - Beyond A > 100
- Summary



Status of RIBF Accelerator

RIBF Facility

- Commissioning in Nov. 2008 … successfull
  - In-beam gamma (Scheit)
  - Coulomb breakup (Nakamura)
  - Interaction cross-section (Ohtubo)
  - New Isotope search (Kubo)

^{238}U … 350 MeV/u
fission production
→ Very powerful for neutron rich nuclei

Final Goal : beam int. = 1pμA for ^{238}U

Big-RIPS : large acceptance (50%)

Status and Plan at RIBF in 2009

http://www.nishina.riken.jp/UsersGuide/accelerator/tecinfo.html

Expected intensities of 345 MeV/nucleon beams at RIBF (pnA)

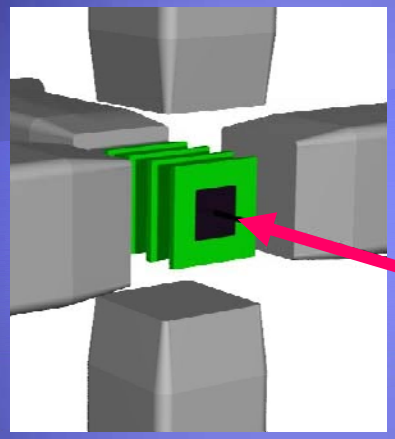
	^{48}Ca	Kr	Xe	^{238}U
April~November 2008	√ 100	√ 30	-	√ 0.3~0.5
April 2009	200	30	10	5

√ Confirmed

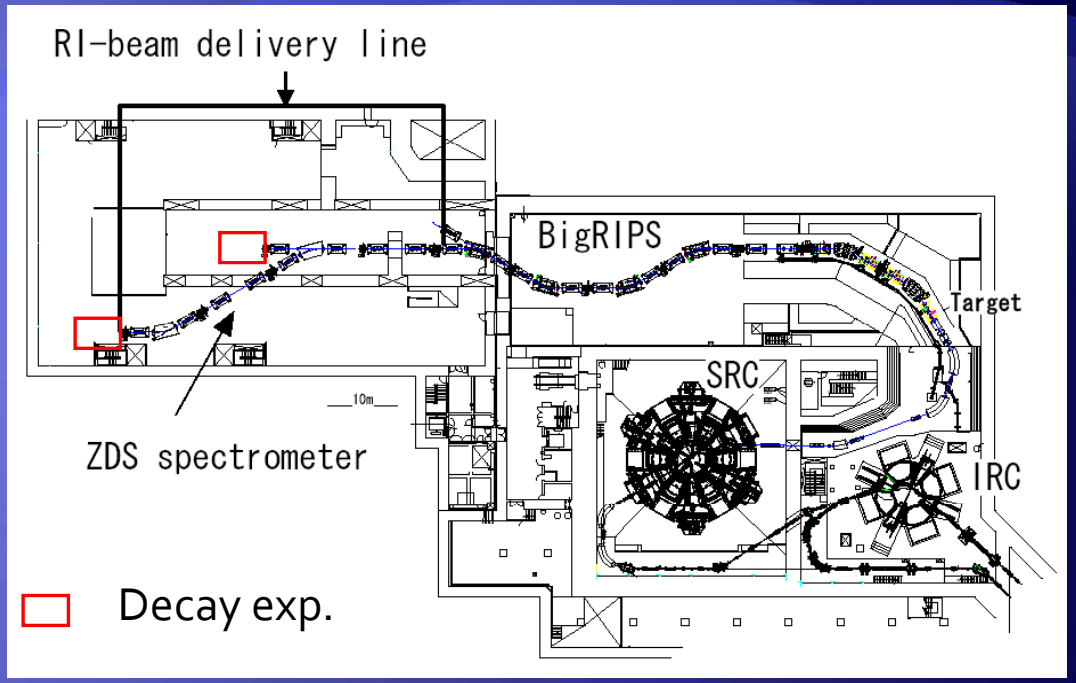
Machine time for FY2009 at RIBF under discussion.

- Oct. 17 – 23 … Xe beam test
- Nov.12 – Nov. 22 … U beam test
- ⇨ Nov. 23 – Dec. 06 … RIBF exp. using U beam (3-5 pnA)
- Dec. 07 – Dec. 10 … Ca be test
- ⇨ Dec. 11 – Dec. 20 … RIBF exp. using Ca beam (200pnA)

Decay Experiments at RIBF



☆Double-Sided Silicon Strip Detector



- RI Beam (~ 200MeV/n)
  - Large momentum spread (~12%) from U fission
- Decay study of rare isotopes
  - High efficiency beta detector ($E_{thr} \leq 50$ keV)
- Cocktail beam
  - Simultaneous $T_{1/2}$ reconstruction, particle by particle.

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Decay Experiment

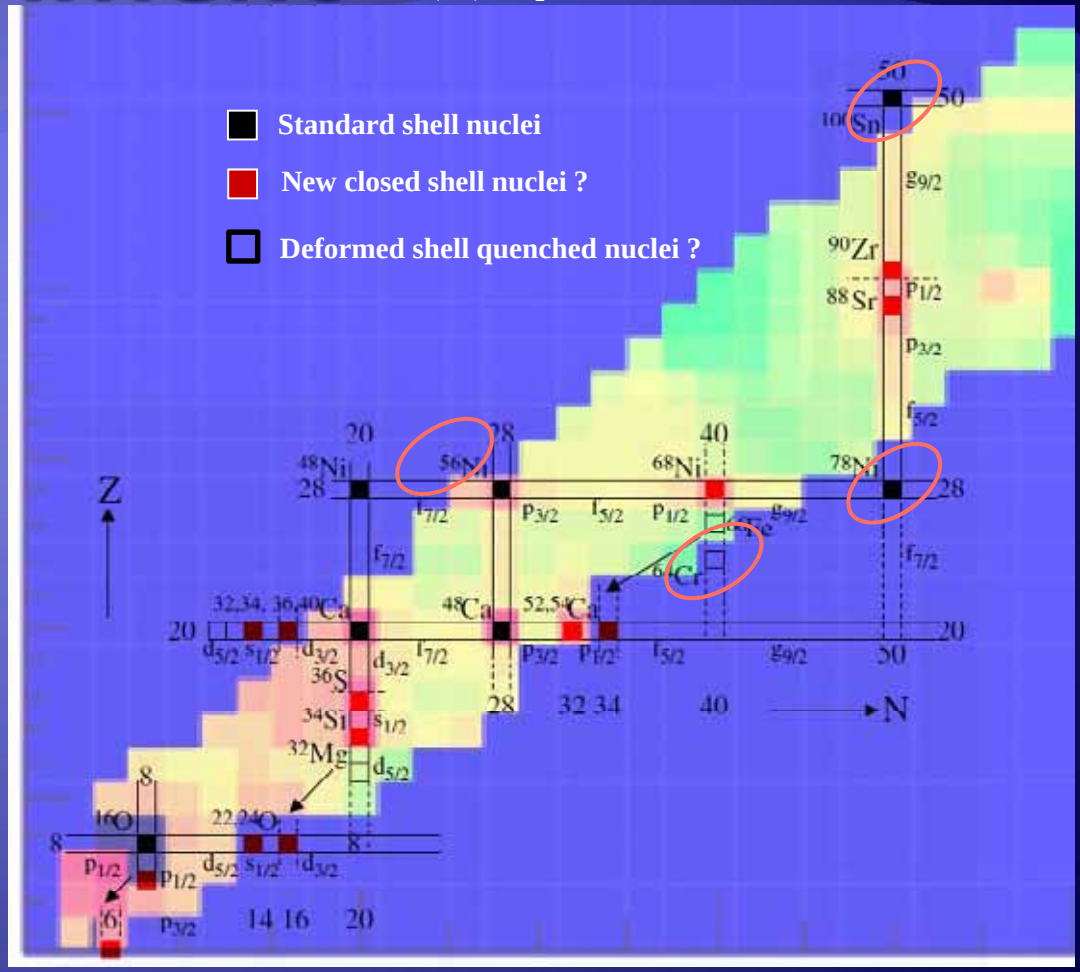
H.Grawe, et al. Eur. Phys. J A 25 (2005) 357
+ E(2+) map from Sakurai-san

Basic Information from Decay

- Decay curve : $T_{1/2}$
- Excited states : $E(2^+)$, ..
- Isomeric states
- Q_β
- Neutron emission (P_n)

Systematic Study

- Nuclear Structure
  - New magic number ?
  - Disappearance?
  - Shell quenching?
  - Deformation?



Inputs

Feedback to Nuclear Theory

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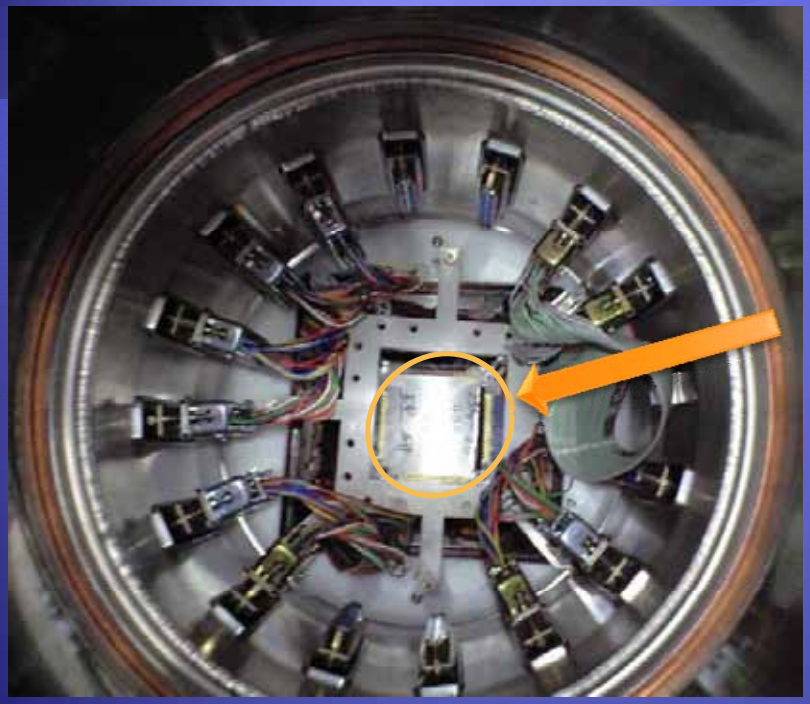
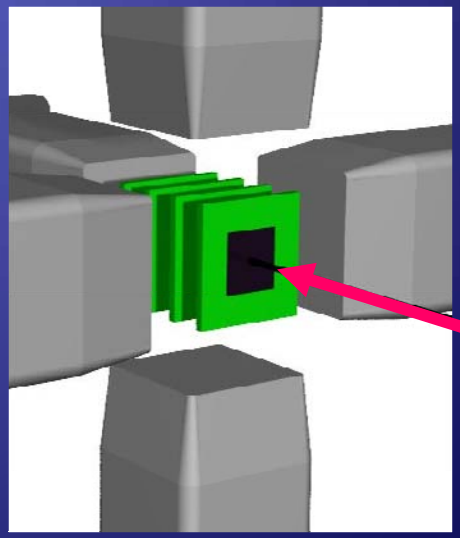
Status of Experiment

DSSD & Ge-detectors (Clovers)

8 ~ 10 stacked Double-Sided-Silicon-Strip-Detectors



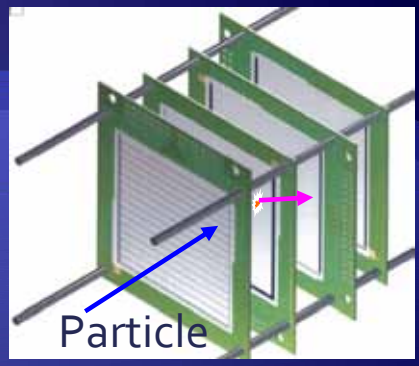
Cooling system

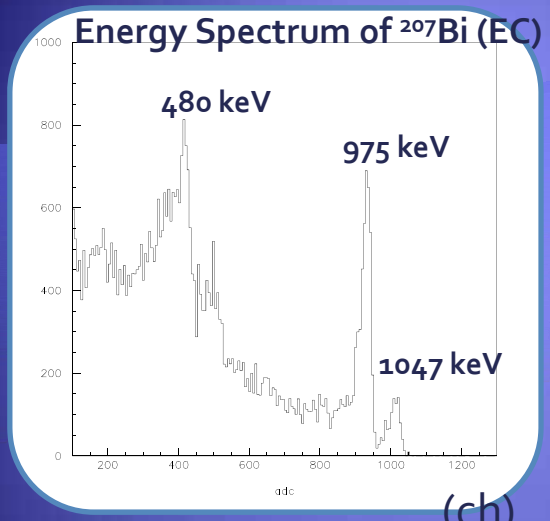


◎ Micron W1 (16 x 16 strips)
9 – 10 detectors

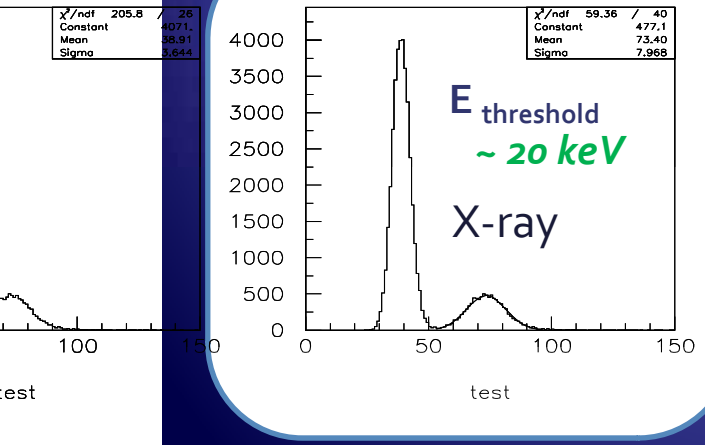
◎ Clover Ge detector
5 detectors

Performance of DSSD

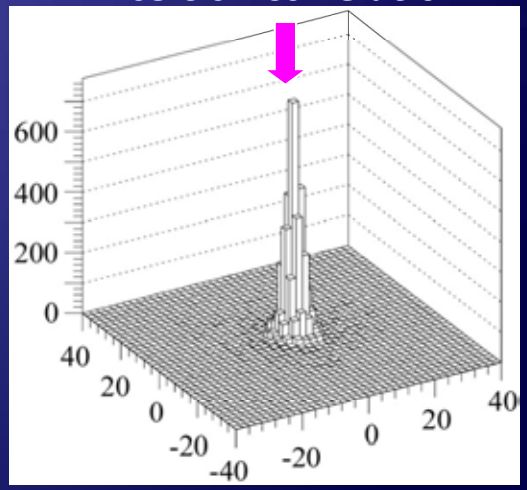




- **Good energy resolution**
  - Particle identification
  - Efficient detection of beta-decay events
- **Event correlation of fragment implants and subsequent decays**
  - 40 strips x 40 strips & 16 strips x 16 strips
- **Multiple Si-layers 9 - 10 layers**
  - Full stopping of incident particles
  - Beta-ray tracking
  - Q_{beta} measurement
- **Readout electronics**
  - Wide dynamic range readout system : 10 keV ~ 5 GeV



Position correlation



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Dual-preamp readout system for wide-dynamic range energy measurement

- Wide dynamic range
  - Incident RI (~ MeV ~ 4 GeV ~)
  - Beta-rays (10keV ~ MeV ~)

It would be essential for Decay Spectroscopy in massive nuclei above A > 100.

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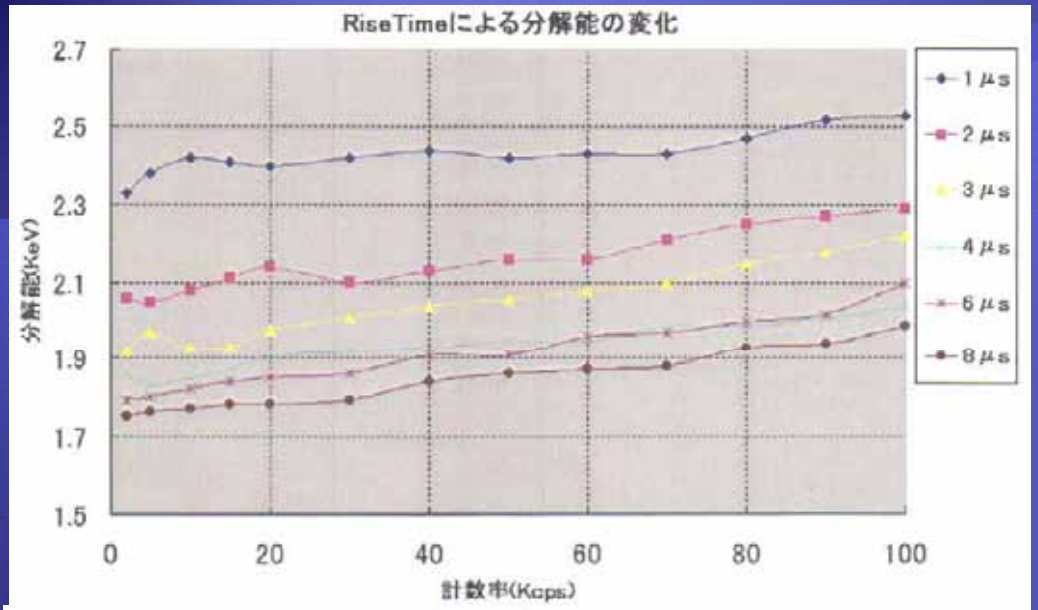
Gamma Detectors

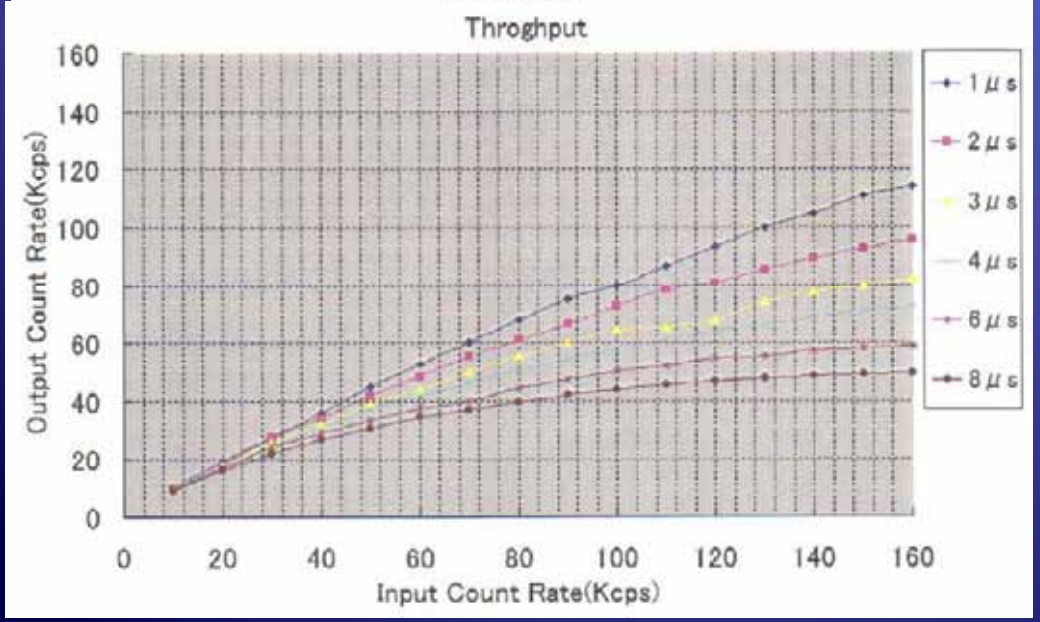
- RIKEN has only 5 x clover detectors available..
  - Installation at close geometry to DSSD.
- Higher efficiency γ-ray detectors

  → Important for γ–γ analysis
  - 14 clover detectors ?
  - Super-Clover detectors ?
  - LaBr3(Ce) arrays ?
- Readout eletronics
  - ORTEC AD314 (CAMAC)
  - Iwatsu 3100A (VME)
  - TECHNO-AP with dead-time less readout

Picture : Clover detector surrounded by BGO detectors

TECHNO-AP + Time-stamp



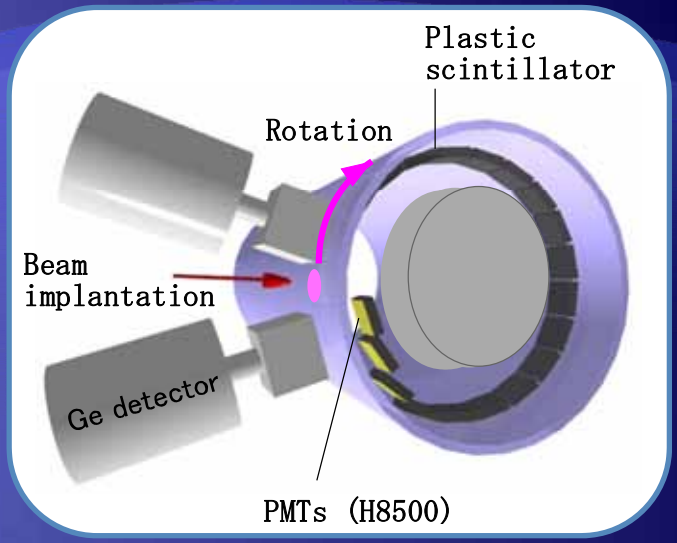


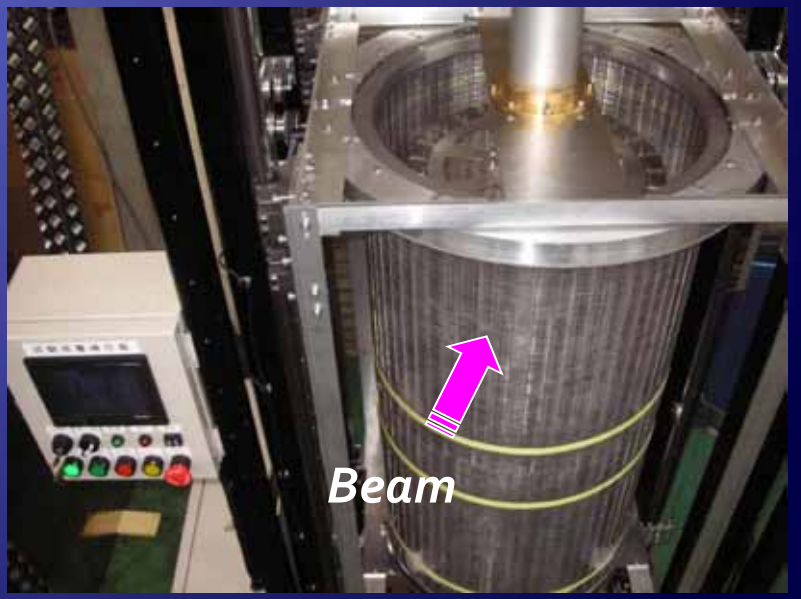
- 8ch
- +/- 1V
- Coarse gain :x 1 ~ 100
- ADC
  - 14bit
- Performance
  - 1.75 KeV @ 1.33MeV
  - 100Kcps throuput

Super-segmented beta counting system : CAITEN

Cylindrical scintillator : (RP-408)
- $4x10^5$ pixel scintillators
- ϕ50 cm x 100 cm
- Ration : ~ 60 rpm ~
- Vertical motion (up / down)

- Air-coupling ~ 3mm gap
- Position resolution
  σ~ 3.8 mm

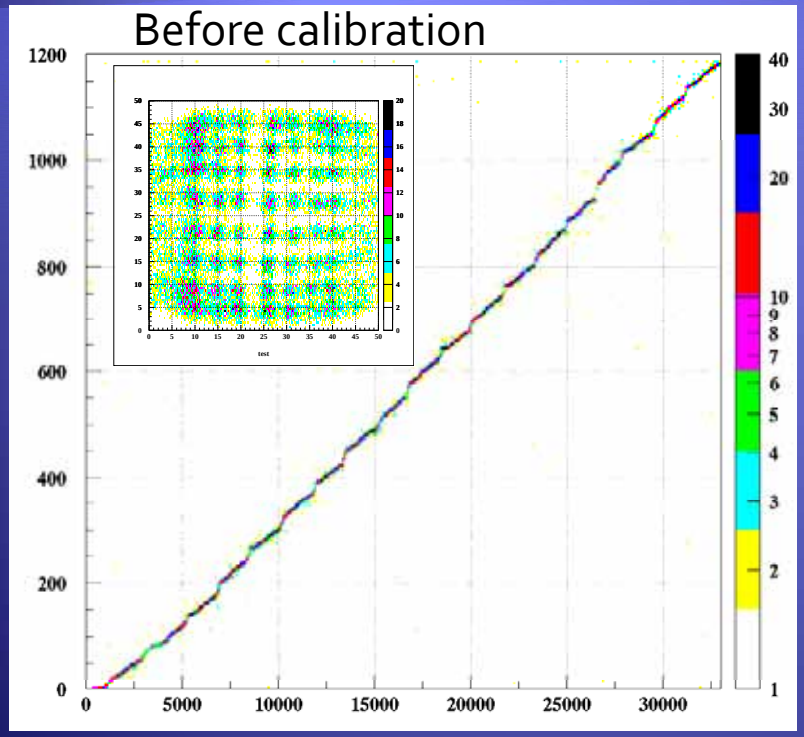




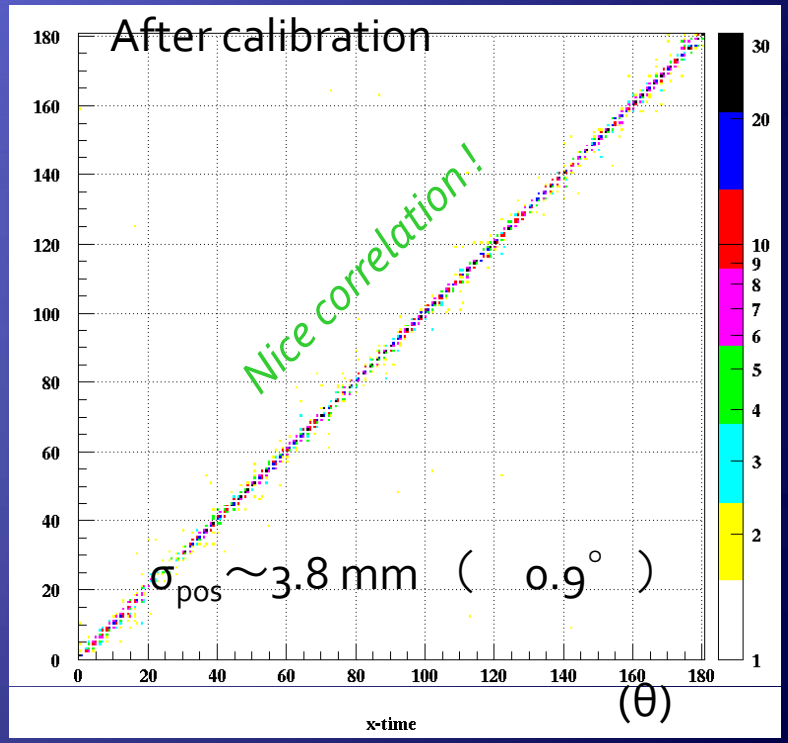
Position Reconstruction

^{90}Sr source attached on the scintillator

Rotation speed
60 rpm (example)



Correction



- ☆ **Demonstration of position calibration.**
- ☆ **Adequate position resolution ~ 3.8mm**

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Perspective
Proposals and Future

Decay Spectroscopy Proposals

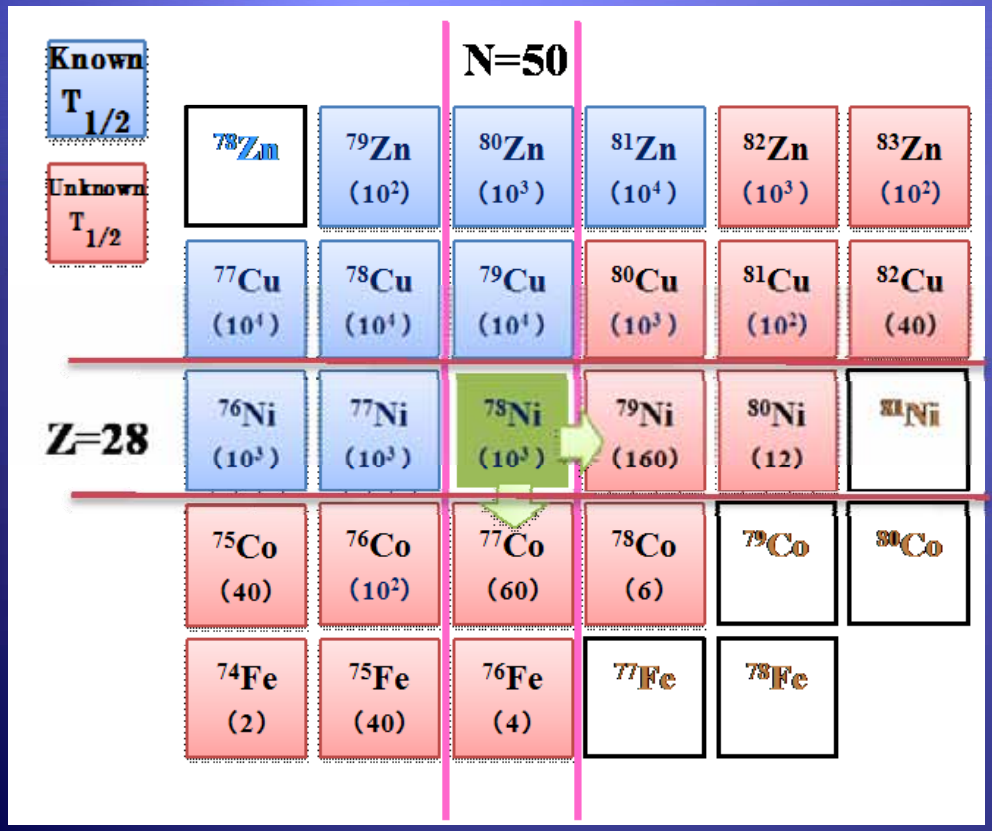
2009 Nov.

- Neutron-rich nuclei
  - Decay study for Co, Ni, Cu and Zn near N=50 shell closure (S.Nishimura)
  - β-decay study of Rb, Sr, Y, Zr isotopes on r-process path (T.Sumikama)
  - Search for long-lived isomeric states in neutron-rich Cd, Ag, and Pd (H.Watanabe)
  - Decay Spectroscopy near ^{64}Cr (Z=24, N=40) (R.Clark)
  - Super-segmented beta-detector "CAITEN" (S.Nishimura)
- Proton-rich nuclei
  - Decay Spectroscopy in the vicinity of ^{100}Sn (M.Lewitwicz)
  - Search for two-proton radioactivity of ^{59}Ge, ^{63}Se, and ^{67}Kr (B.Blank)

More proposals ..

Yield Estimation around ^{78}Ni

U-beam int. : ~ 1 pnA (5 pnA in 2009 !)
Beam time : 2 days (N<50),
2 days (N=50),
3 days (N>50)



… Not discovered

^{81,82}Cu, ^{79,80}Ni, ^{75,76,77,78}Co, ^{74,75,76}Fe

Red … No decay information

^{82}Zn, ^{83}Zn, ^{80}Cu, ^{81}Cu, ^{82}Cu, ^{79}Ni, ^{80}Ni,

^{75}Co, ^{76}Co, ^{77}Co, ^{75}Fe

Excited states (depends on statistics..)
- E(2+)
- Isomeric states ($T_{1/2}$, levels)
- Neutron Emission P_n

New beam line optics with two degrader modes
→ may enables us to study more species of RI.

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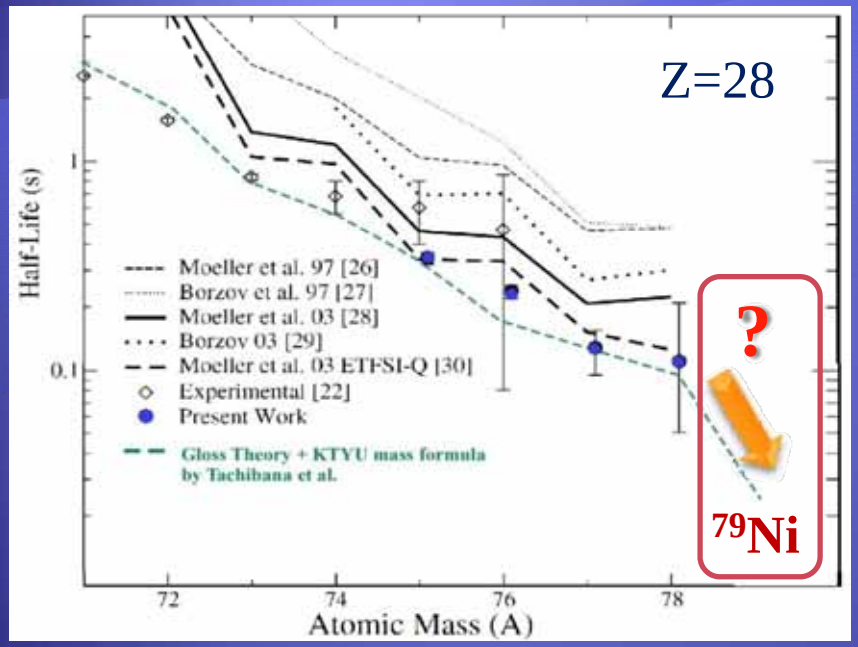
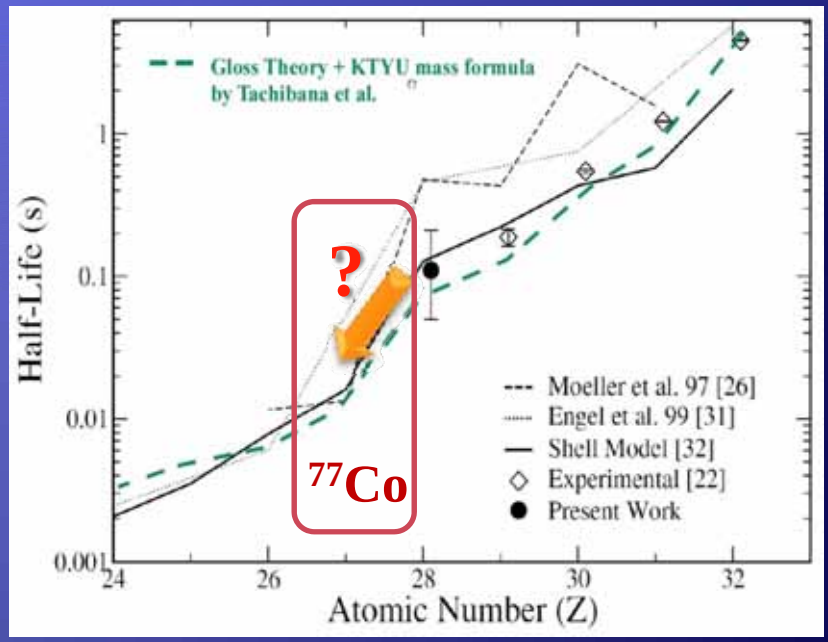
Short Half-lives of Nuclei beyond ^{78}Ni ??

Magicity at Z=28 and N=50 ?

P.T.Hosmer et al., PRL 94, 112501(2005) mod.





★Higher production yield ? … ^{78}Ni ~ 1 / day (MSU) → 10^3 / day in 2009?

★Higher detection efficiency ? … ~ 40% → 80% ~?

more accurate measurement for ^{78}Ni at RIBF

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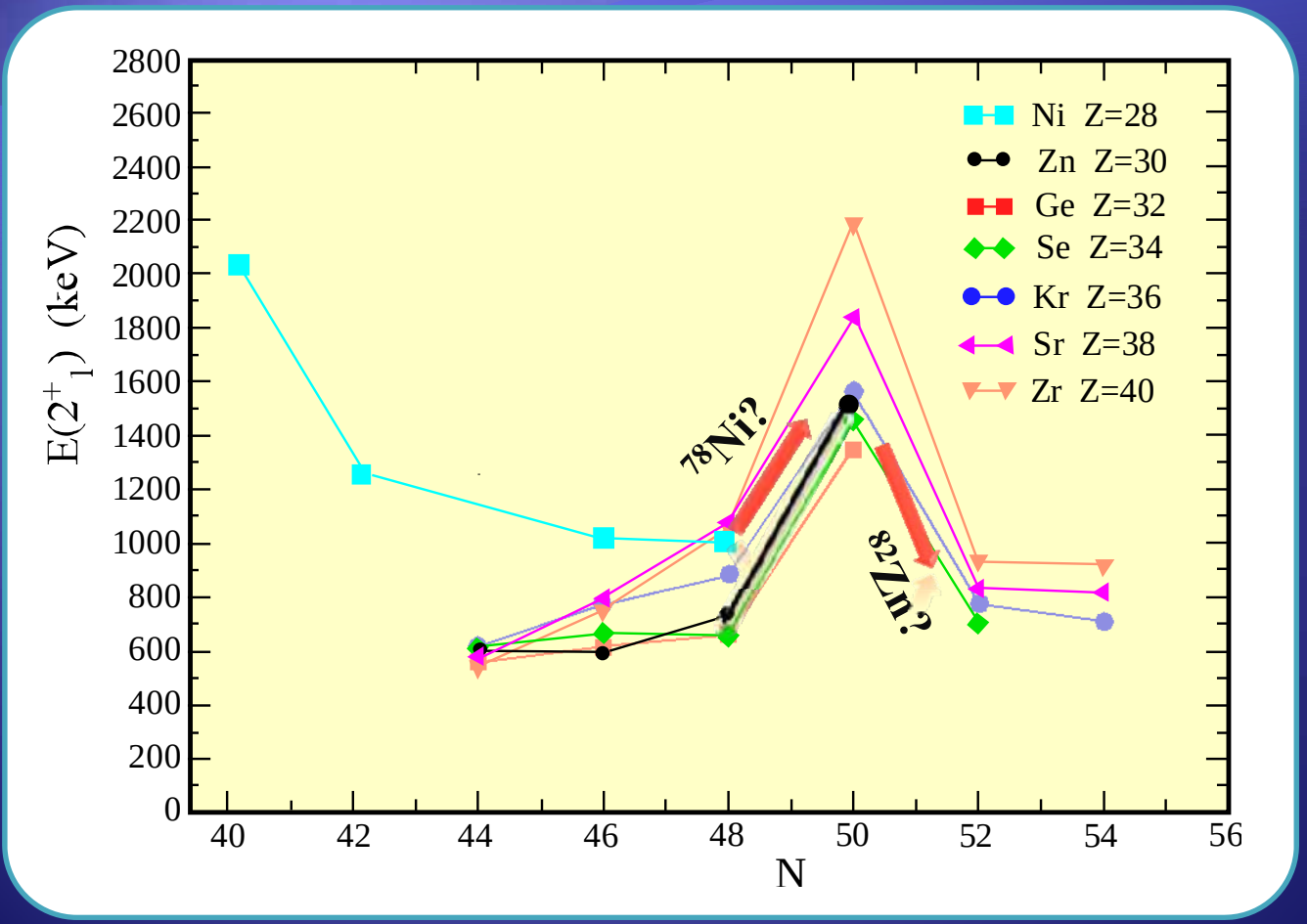
Excited States E(2+) around N=50

O.Perru, et al. EPJA 28 (2006) 307.
J.V.Walle, PRL 99 (2007) 142501

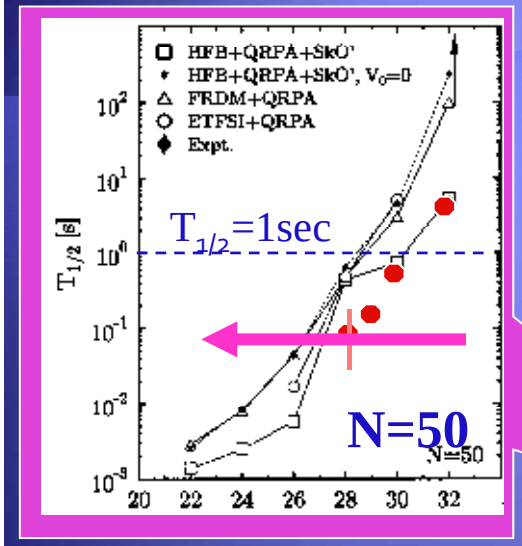


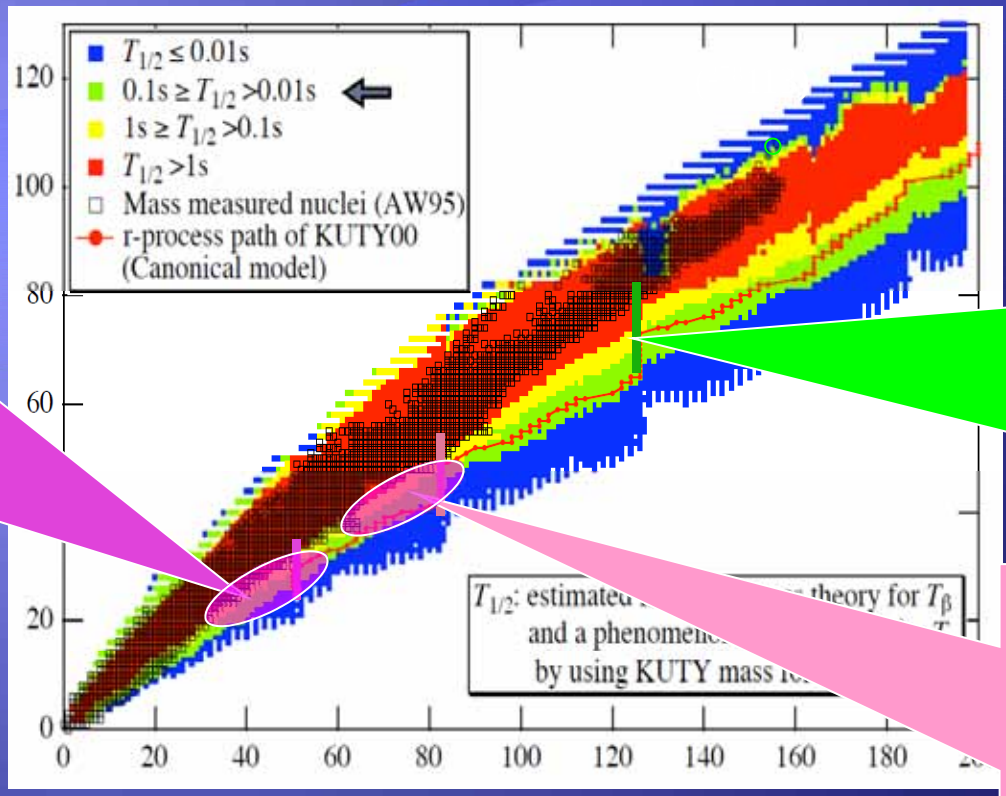
What about ^{82}Zn and ^{78}Ni?

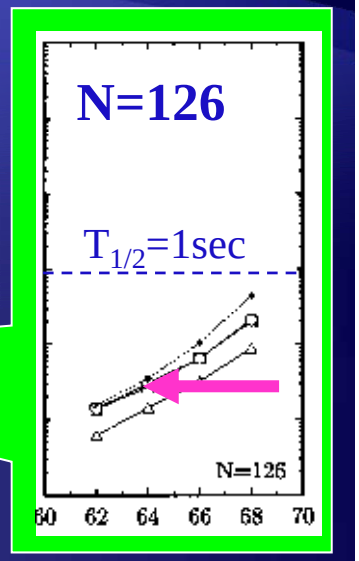
Benchmark to Nuclear Theory

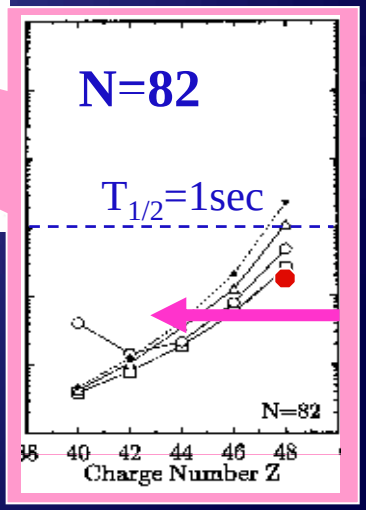
Half-life (T1/2) : Yield & Statistics

Cal. by H.Koura, et al.









- Half-life measurement
  - one month operation with ^{238}U (1pnA) fission products
    - 40 isotopes (N~50)
    - 70 isotopes (N ~ 80)
- Suitable for proton-rich side with bad purity condition.

Summary

- RIBF will provide an intense U beam
  - 0.01 pnA in 2007
  - 0.4 pnA in 2008
  - ~ 5 pnA in 2009
  - 1000 pnA in 20XX?
- Decay spectroscopy will provide important information for nuclear structure and astrophysics.
  - New isotopes, T1/2, isomer, E(2+), P_n, Q_β, …
- Decay Experiments at RIKEN
  - Preparation of detector systems , DSSD & Ge & CAITEN
- Plan for decay experiment
  - 2009 … ^{78}Ni (+ ^{110}Zr)
  - 2010 ~ … ^{100}Sn, ^{64}Cr, ^{128}Cd, ^{59}Ge (^{63}Se, ^{67}Kr, ^{48}Ni), …
- In Future..
  - Light nucleus near drip-line (…, F, Ne, Na, Mg, …)
  - ^{128}Pd , ^{94}Ag, …