



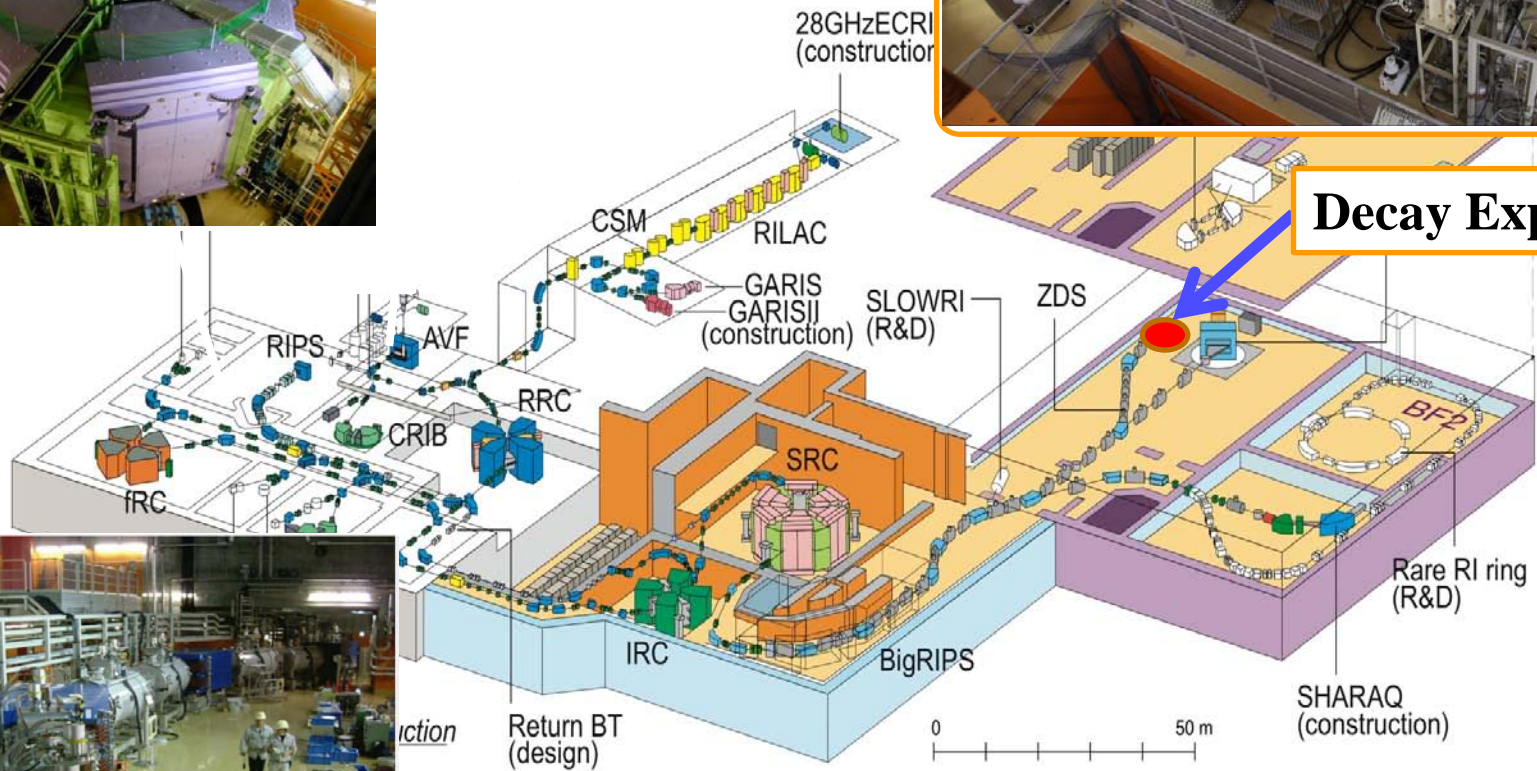
# Decay spectroscopy of very neutron-rich nuclei at RIBF

Shunji NISHIMURA  
( RIKEN Nishina Center )

for EURICA\* collaboration

(\*) ... *EUROBALL RIKEN Cluster Array*

# Location of Decay Station



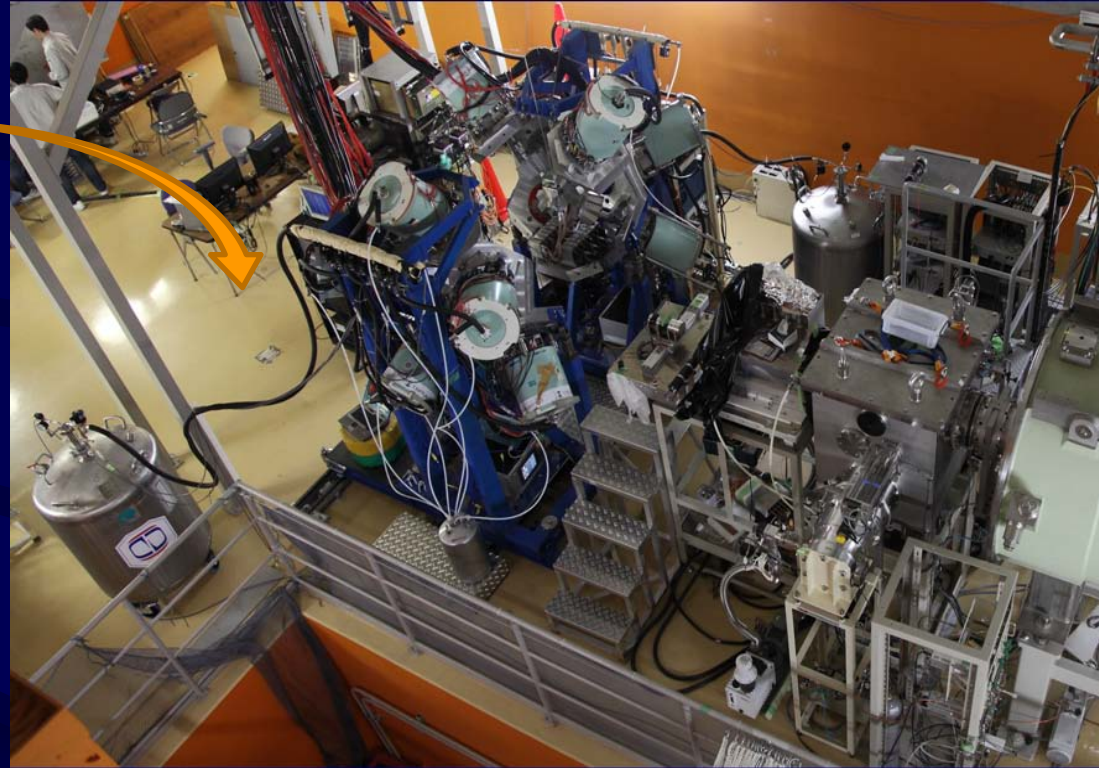
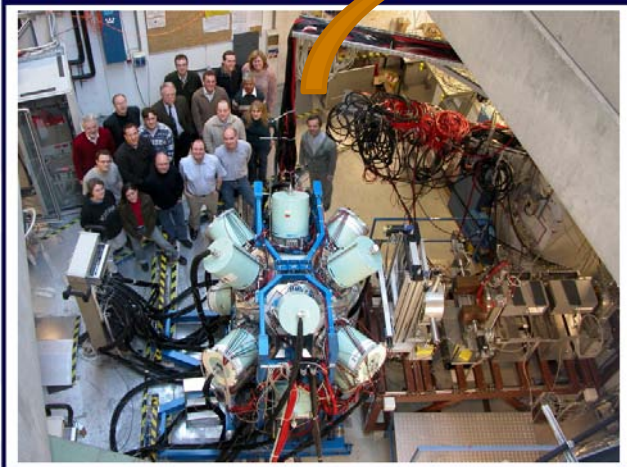
**Decay Exp.**

$^{238}\text{U}$  ... 345 MeV/u

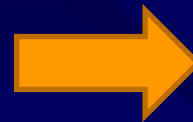


# EURICA Project at RIBF

(EUROBALL RIKEN Cluster Array)



Euroball Cluster detectors  
Support structure  
Readout electronics  
used for GSI-RISING



2011 Nov.

RIKEN RIBF  
(Japan)



# Upgrade : 2009 → 2012

## U-beam intensity

- 0.2 pA → ~ 10 pA ... x 50 times

## Gamma-ray detector

- 4 Clover detectors (Det. Effi. ~1.5% at 0.662 MeV)

→ 12 Cluster detectors (Det. Eff. ~ 15 % at 0.662MeV)

... x 10 times

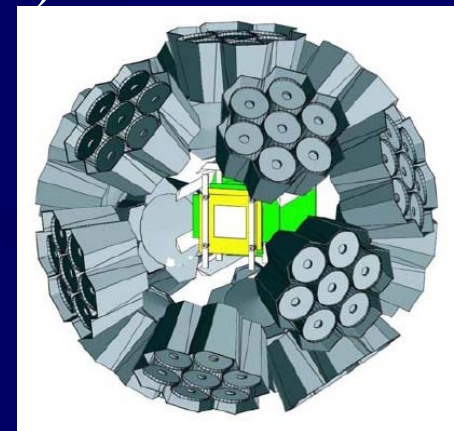
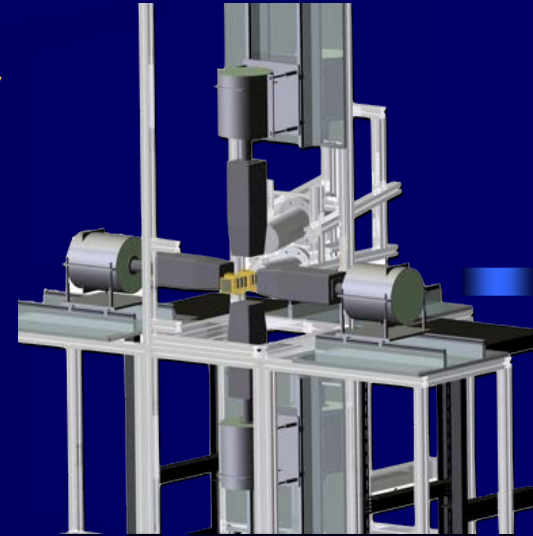
( → gamma-gamma coincidence ... x 100 times )

## Beta counting system

- 16 x 16 pixels x 7 layers = 1792 pixels

→ 40x60 pixels x 8 layers = 19200 pixels

... x 10 times



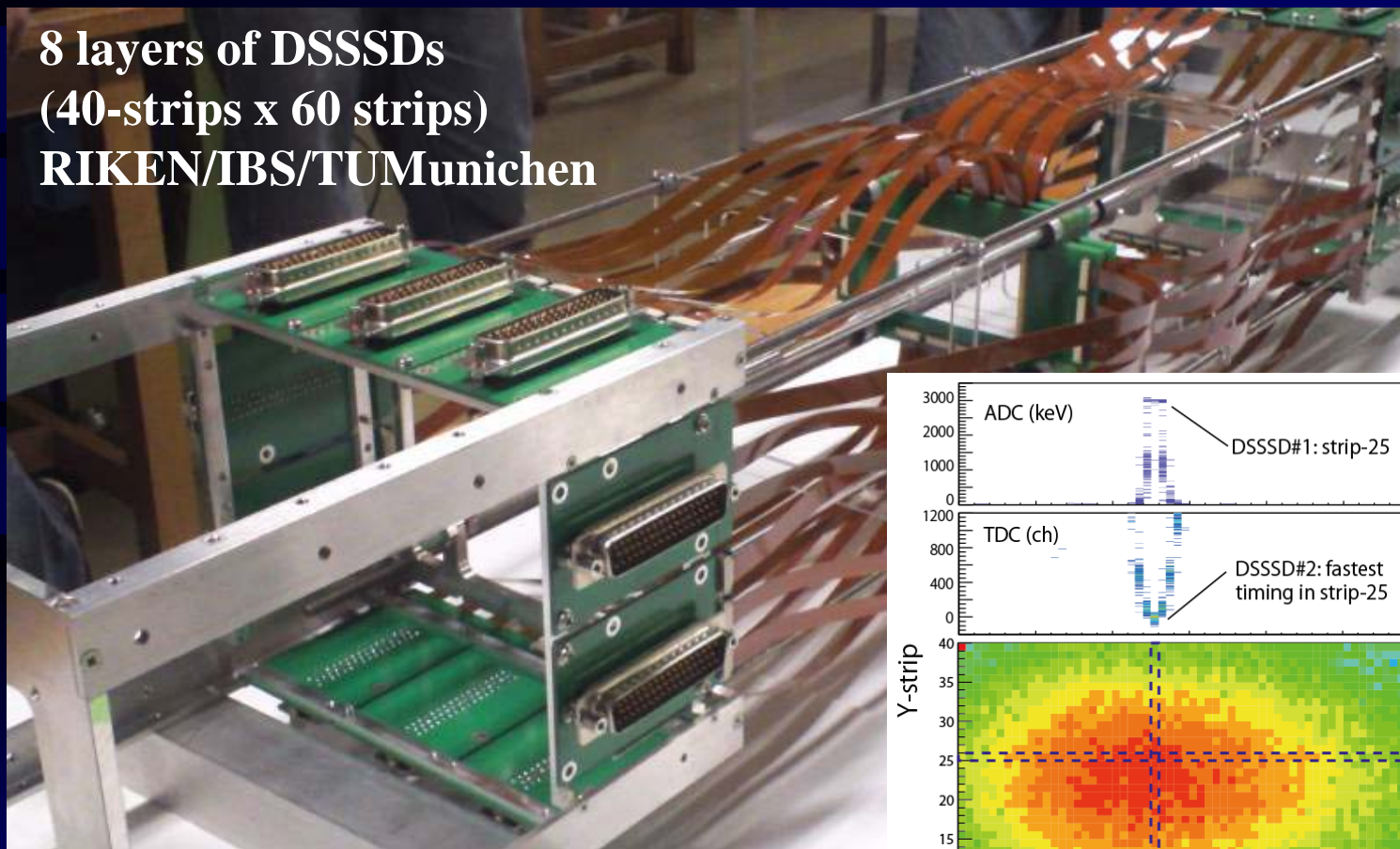




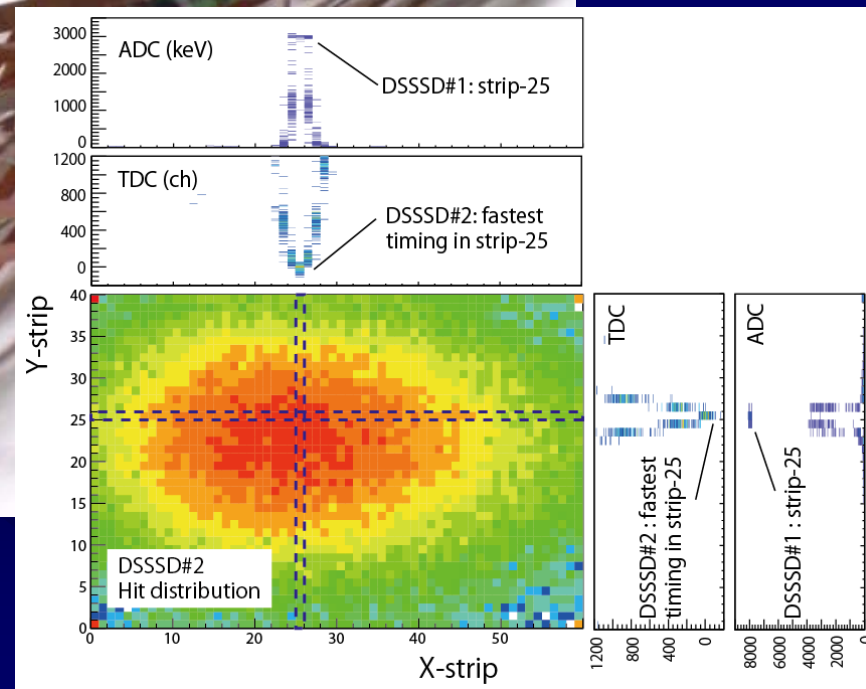
# New Beta Counting System : WAS3ABi

(Wide-range Active Silicon-Strip Stopper Array  
for Beta and ion detection)

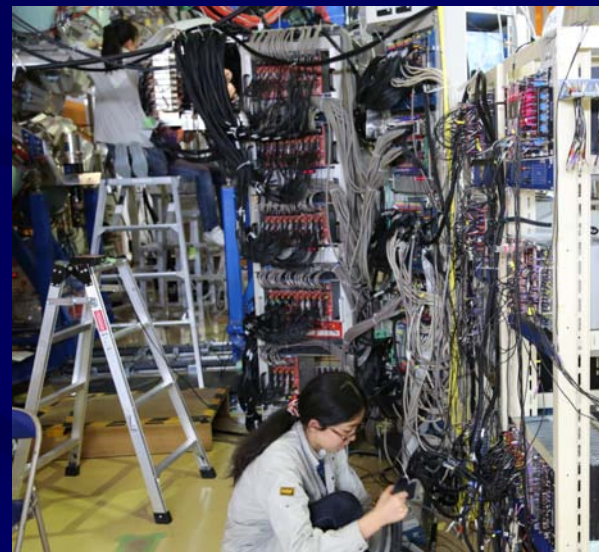
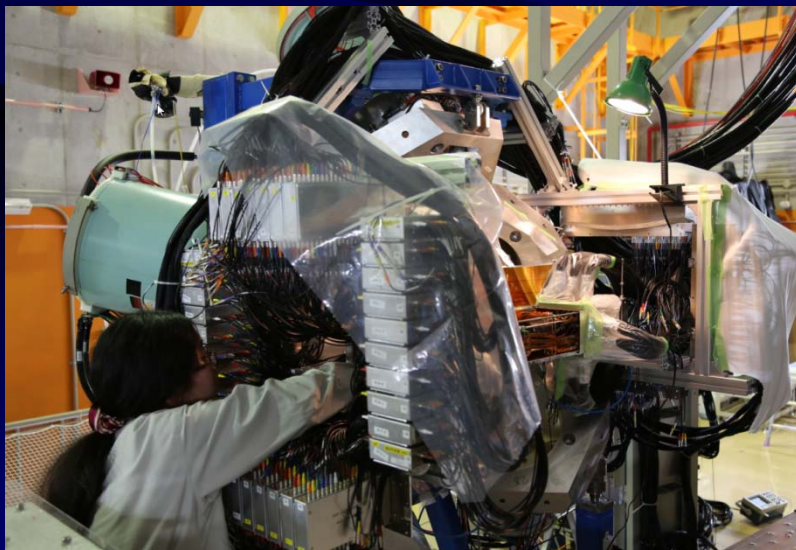
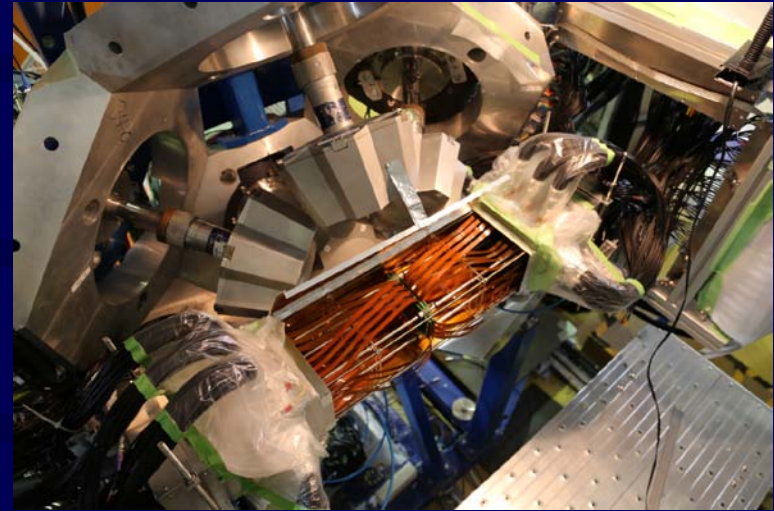
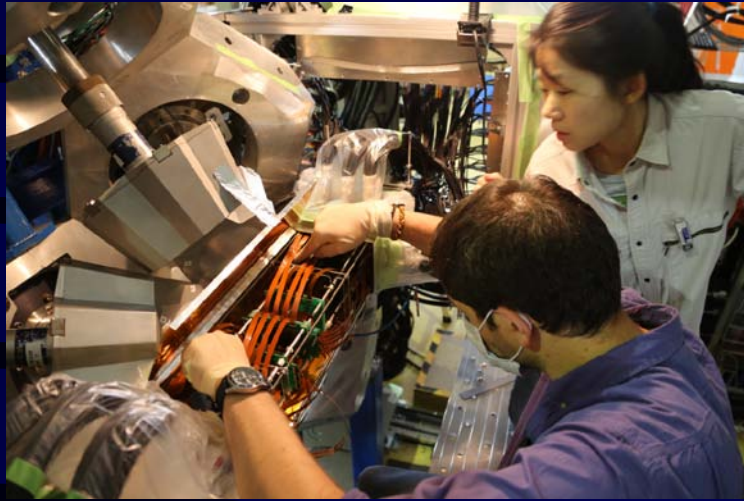
8 layers of DSSSDs  
(40-strips x 60 strips)  
RIKEN/IBS/TUMunichen



In total, 14,400 pixels  
(19,200 pixels)

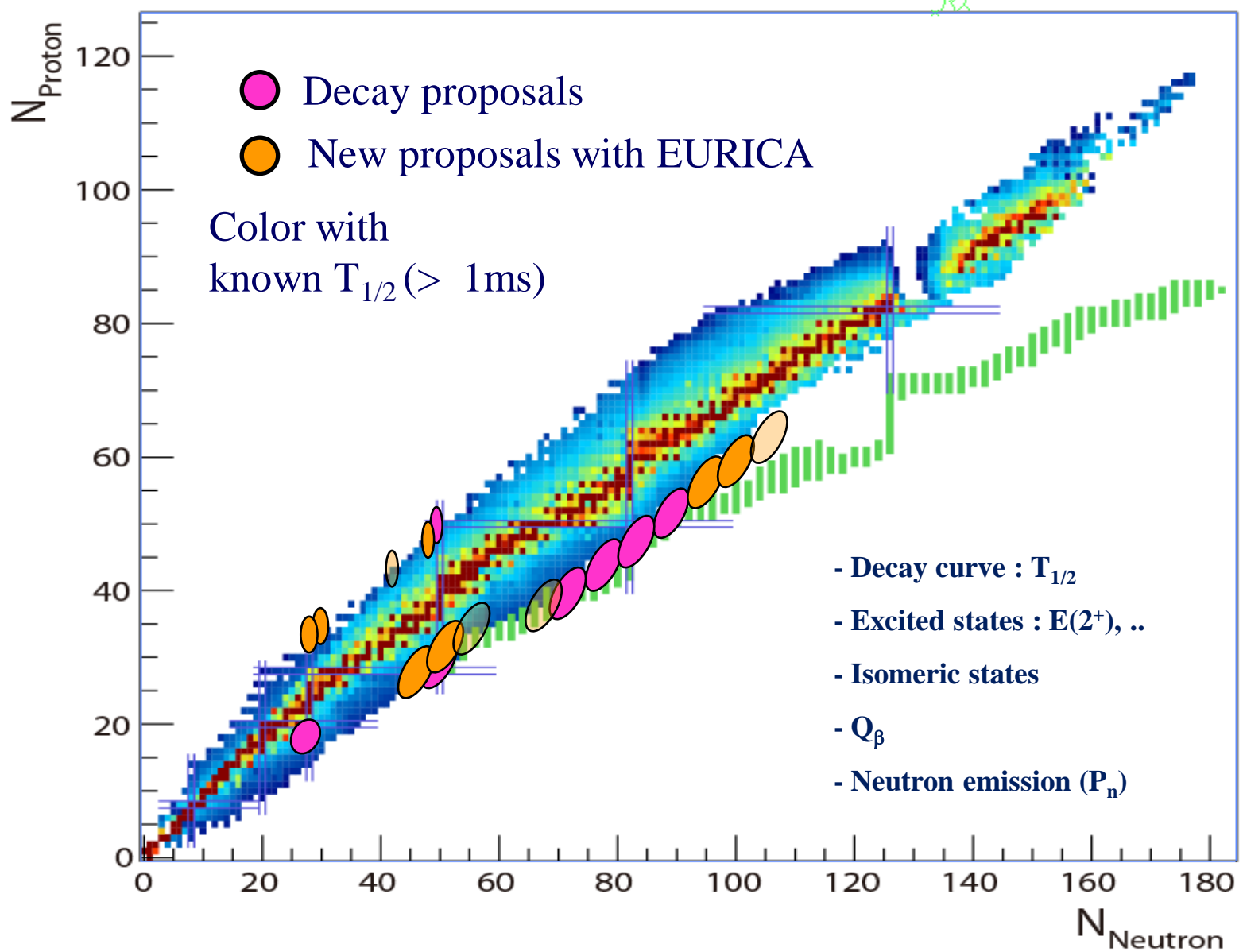


# U-Beam Campaign 2012





# Decay Proposals at RIBF





# EURICA Campaign in 2012

[<sup>18</sup>O beam] 100 ~ 200 pnA

Mar.29 – 31 (2 days)

... Commissioning I (Nishimura/Doornenbal)

April 16 – 18 (2 days)

... Commissioning II (Nishimura/Doornenbal)

[<sup>124</sup>Xe beam] 10 ~ 27 pnA

June 18 – 29 (6 days)

... <sup>94</sup>Ag, <sup>96</sup>Cd, <sup>98</sup>In (Boutachkov/...)

[<sup>238</sup>U beam] 6 ~ 12 pnA

Nov.6 – 16 (7.5 days)

... <sup>78</sup>Ni (Nishimura)

Nov.16 – 29 (10 days)

... <sup>128</sup>Cd / <sup>128</sup>Pd (Watanabe/Lorusso)

Nov.30 – Dec. 5 (5 days)

... <sup>138</sup>Sn / <sup>132</sup>Cd (Simpson/Jungclaus/Gadea)

Dec. 5 – 9 (-)

... <sup>126</sup>Pd / <sup>115</sup>Nb (Watanabe/Lorusso)

Dec.12 – 18 (5.5 days)

... <sup>81</sup>Cu (Niikura)

In total : 38 days, beam on target



# EURICA 2013

[<sup>238</sup>U beam] 5pnA → 10pnA

4.5 days ... A ~ 140 (Odahara/Lozeva/Moon)

8.5 days ... Sumikama

5.5 days ... Z ~ 60 (Ideguchi/Simpson)

5.5 days ... ~ <sup>75</sup>Ni (DeAngelis)

+ Giacomo (parasitic in-beam  $\gamma$ )

[<sup>124</sup>Xe beam]

9 days ... ~ <sup>100</sup>Sn (Lewitowicz/Gernhaeuser/Nishimura)

4 days ... ~ <sup>73</sup>Sr (Lorusso)

In total ~ 37 days

\*Remaining programs (A-Rank)

[<sup>78</sup>Kr beam] ~ <sup>66</sup>Se ... Rubio/Fujita/Gelletly (5 days)

~ <sup>59</sup>Ge ... Blank (6 days)

[<sup>238</sup>U beam] ~ <sup>170</sup>Dy ... Watanabe/Soederstrom/Regan/Walker (10.5 days)

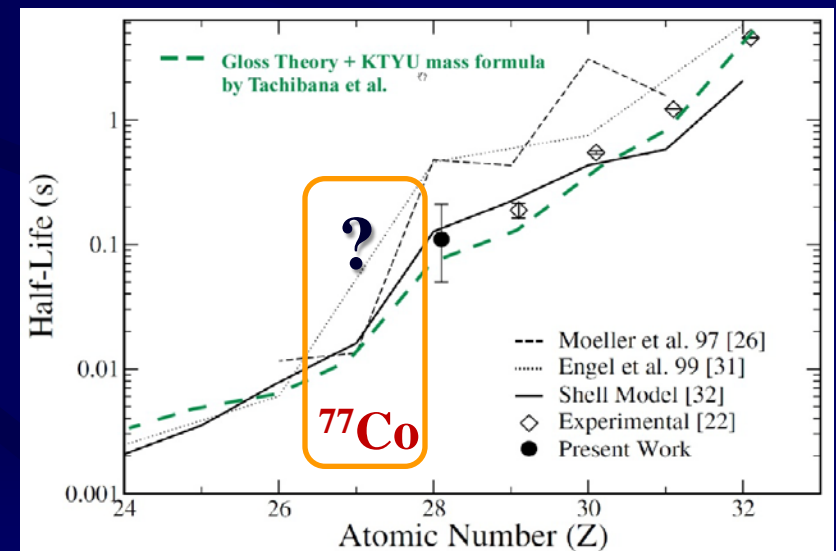
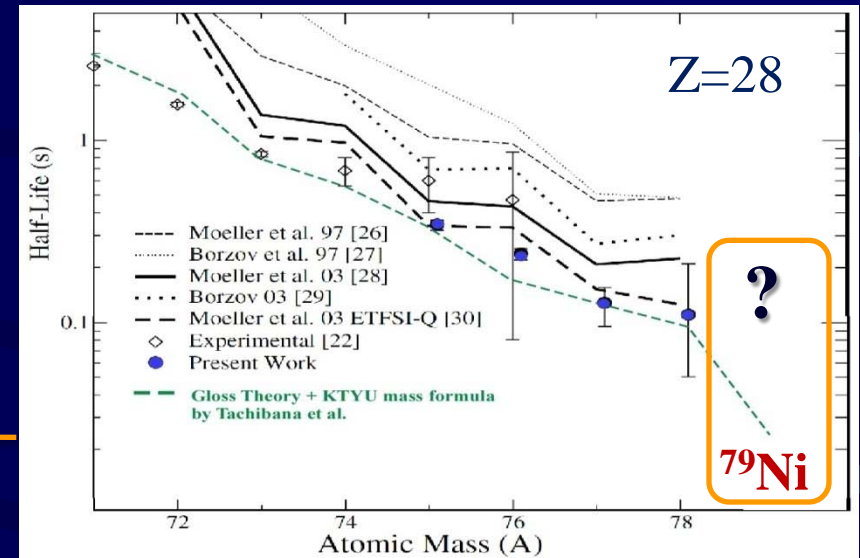
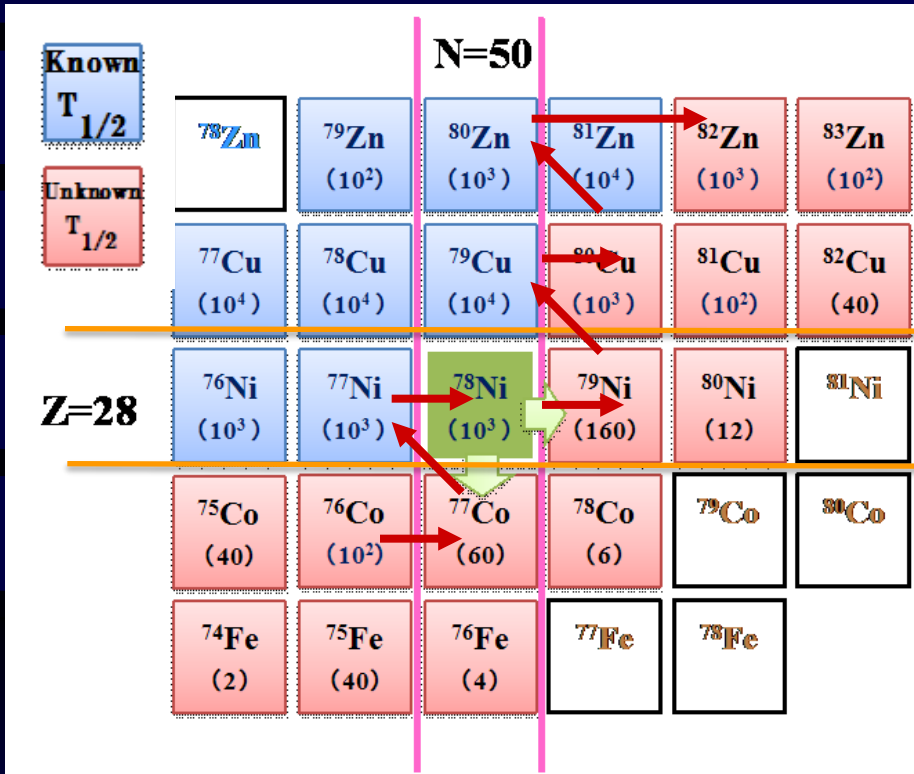
EURICA U-beam Campaign  
(Survey of very neutron-rich nuclei)

$^{78}\text{Ni}$  region ( $Z\sim 28$ ,  $N\sim 50$ )



# Beta-decay Half-lives around $^{78}\text{Ni}$

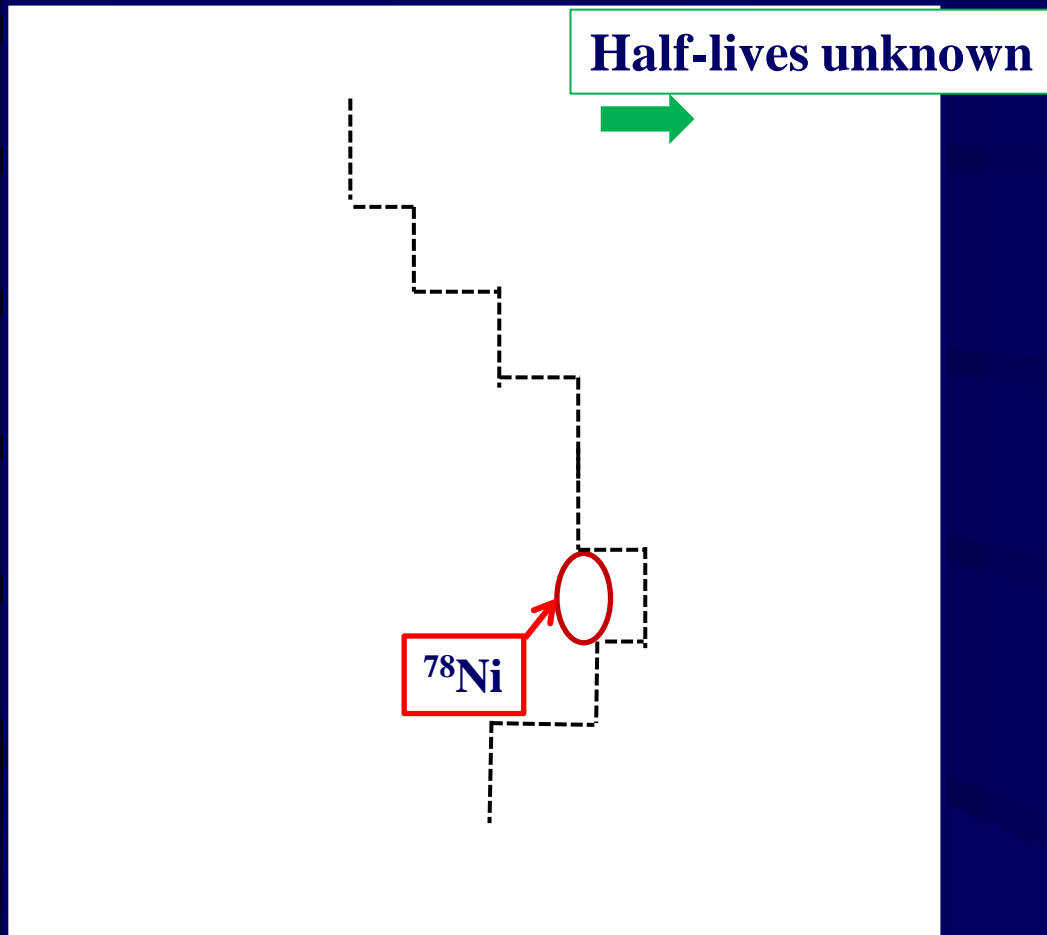
RIBF Proposal in 2007



New data from ORNL

- Madurga, PRL 109 (2012)
- Mazzocchi, PRC 87 (2013)

# Beam production around $^{78}\text{Ni}$ region



Spokesperson:  
S.Nishimura

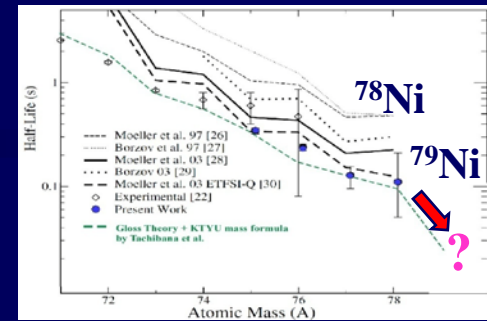
Implantation rate  
= 20 ~ 50 pps

*New isotopes  
(Candidates)*

Additional + 40% of data to be included. (+ Niikura exp.)  
→ 10 k of  $^{78}\text{Ni}$  produced.

# $^{78}\text{Ni}$ Decay Half-life

Hosmer (MSU)  
PRL (2006)



Preliminary

Gated on  $\beta$ -delayed  $\gamma$

Preliminary

Z. Xu (PhD Student)

Very nice decay spectra obtained in the last decay campaign.

What about isotope beyond  $N=50$  ( $^{79}\text{Ni}$ )? Below  $Z=28$  ( $^{77}\text{Co}$ )?



# Beta-decay half-lives around $^{78}\text{Ni}$

Z.Xu (PhD)

FRDM+QRPA

**Z=28**

$^{78}\text{Ni}$

RIBF  
Preliminary

**N=50**

$^{78}\text{Ni}$

FRDM+QRPA

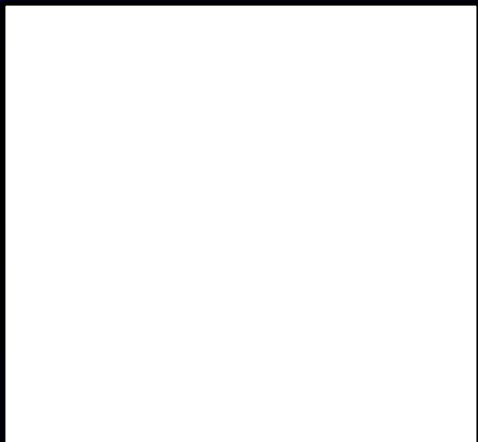
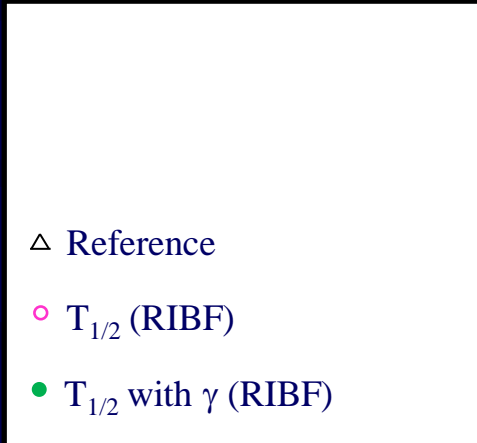
KTUY+GT2

# Half-lives around $^{78}\text{Ni}$



- △ Reference
- $T_{1/2}$  (RIBF)
- $T_{1/2}$  with  $\gamma$  (RIBF)

Preliminary

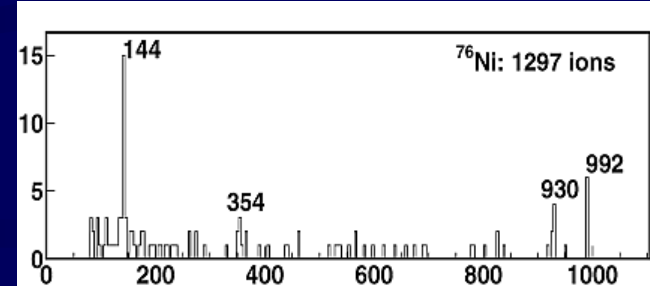


# $^{76}\text{Ni}$ Isomer (known)

RIBF010

354 keV  
↓

Preliminary

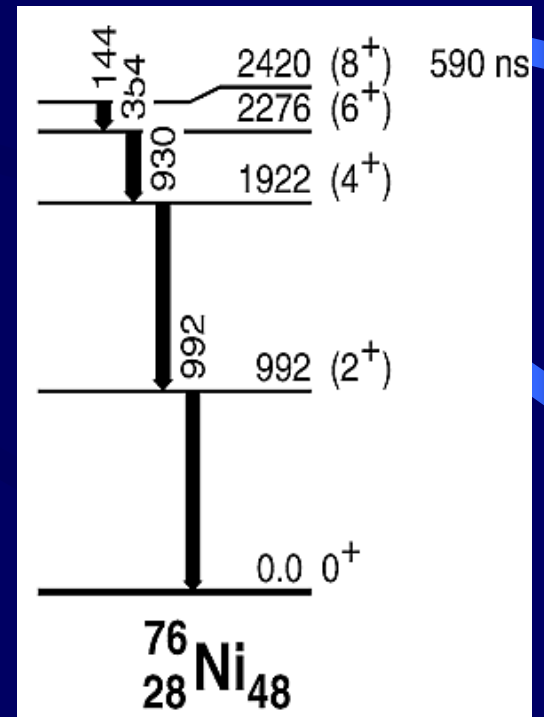


C.Mazzocchi, PLB 622 (2005)

144 keV

Preliminary

930 keV  
992 keV





# Beta-delayed gamma



730 keV



2<sup>+</sup>

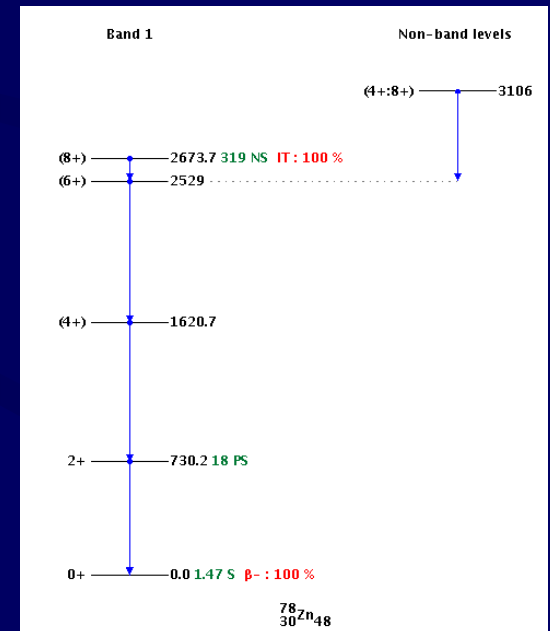
Preliminary

4<sup>+</sup>

6<sup>+</sup>

Preliminary

Yagi @ Osaka Univ.  
Xu @ Univ. Tokyo



# Heavier Isotopes

~  $^{128}\text{Pd}$  region

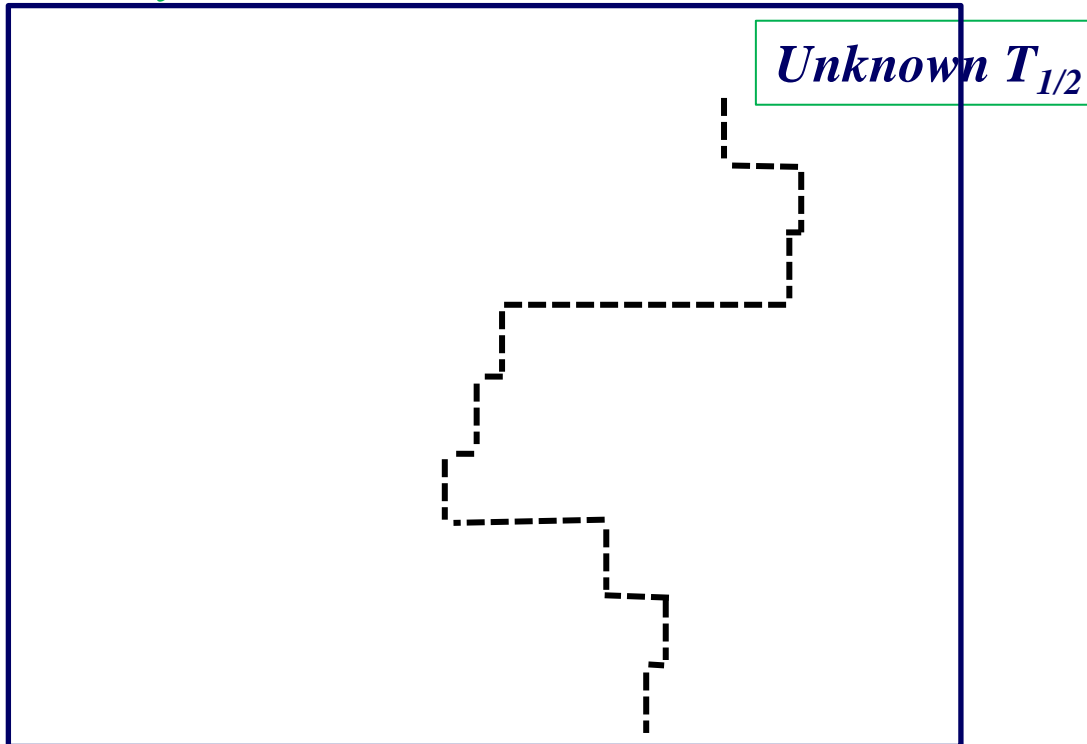
~  $^{115}\text{Nb}$  region

~  $^{138}\text{Sn}$  region

# $^{128}\text{Pd}$ setting (5 days)

Spokespersons:  
H. Watanabe  
G. Lorusso

*Preliminary*



*Candidates of  
New Isotopes*

Analysis in progress

# $^{115}\text{Nb}$ Setting (1 day)

Spokespersons:  
H.Watanabe  
G.Lorusso

*Preliminary*

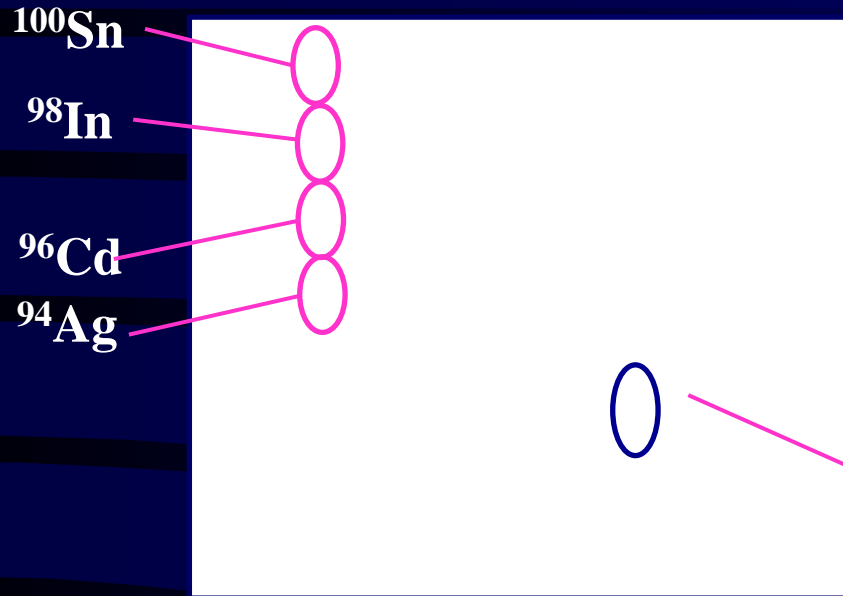
Analysis in progress





$^{98}\text{In}$ ,  $^{96}\text{Cd}$ ,  $^{94}\text{Ag}$ , ..

*RIBF-083 (P.Boutachkov)*

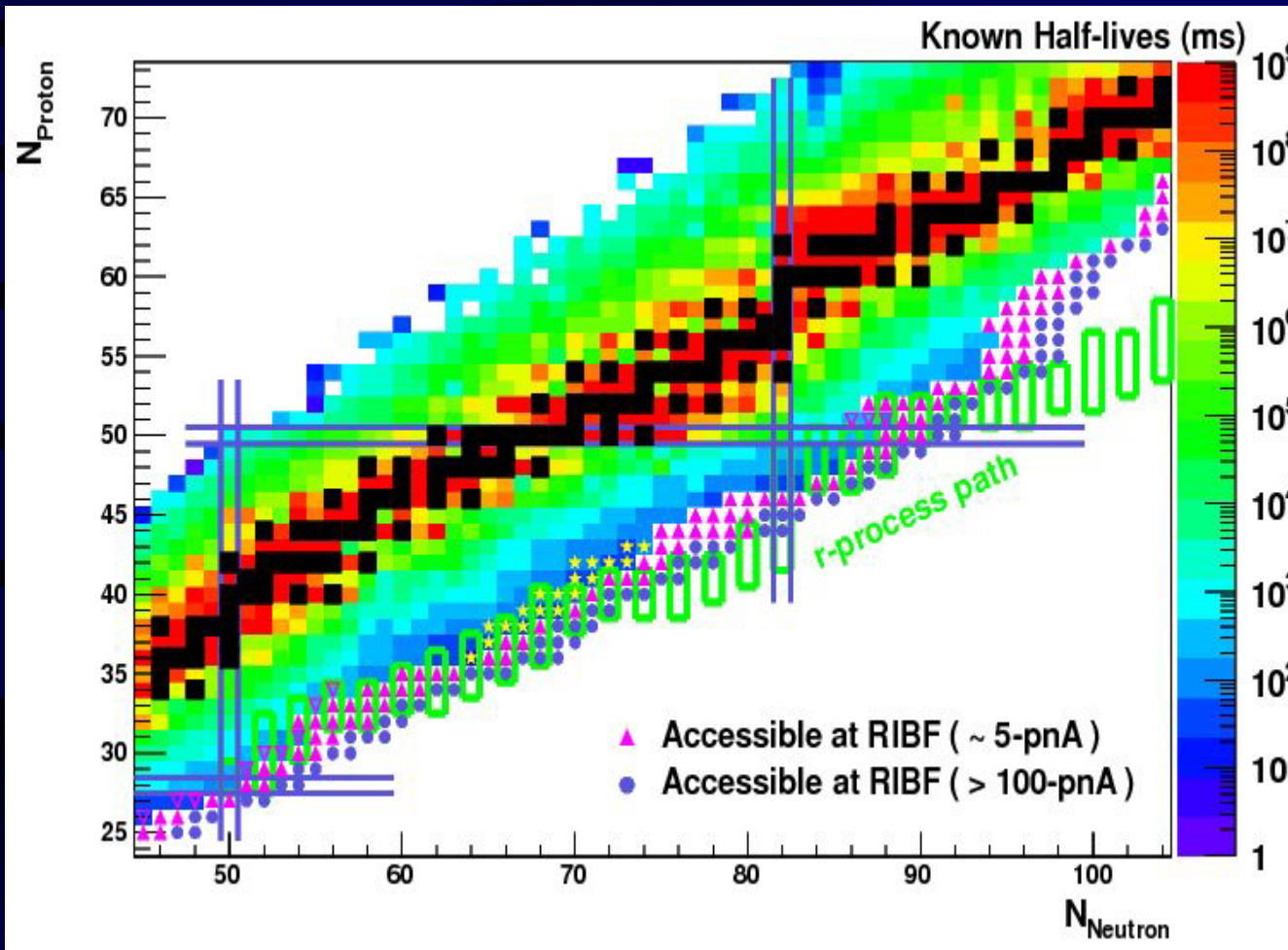


$^{96}\text{Pd}$  isomer



In Future..

# In five years... (U-beam int. $\geq 100$ pnA!?)



SN, PTEP (2012)

Several hundreds of new beta-decay half-lives in five years.

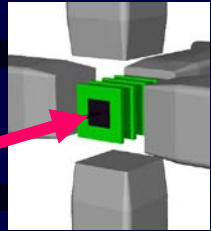
→ Significant contribution in nuclear structure and r-process nucleosynthesis.

# Decay Programs (Past and Future)

2009



$\beta$ - $\gamma$



$^{110}\text{Zr}$  region  
(3-days)

\*PLB 696, 186 (2011)

\*PRL. 106, 052502 (2011)

PRL. 106, 202501 (2011)

PLB 704, 270 (2011)

2010



2011



ject

$^{78}\text{Ni}$  region (7.5-days)

$^{115}\text{Nb}$  -  $^{128}\text{Pd}$  (11-days)

$^{136,138}\text{Sn}$  region (5-days)

$^{81}\text{Cu}$  region (11-days)

::

Total beam time: ~100 days

2012

2013

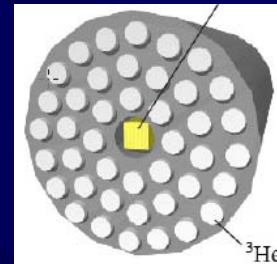
$\beta$ - $\gamma$ -n

[ high efficiency ]

$^3\text{He}$  counters (x 27)

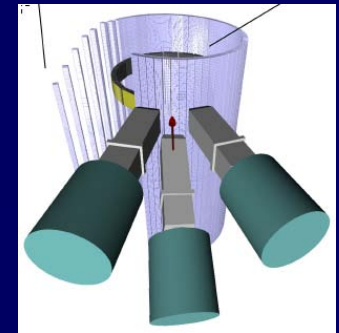


Neutron detectors



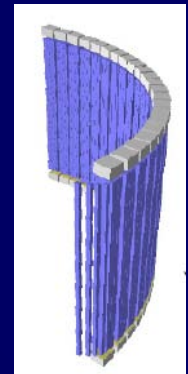
$\beta$ - $\gamma$ -n

[ fast timing ]



Neutron detectors  
(TOF)

LaBr3 detectors



[ New Collaboration ]



# SUMMARY

## RIBF Accelerator

- High intensity radioactive beam
  - U-beam ...  $\sim 10$  pnA, Xe-beam ...  $> 20$  pnA

## BigRIPS/ZeroDegree Beam-line

- Large acceptance beam line
- Cocktail beam & Particle identification

## Decay Station

- High efficiency gamma-ray detectors  
(Euroball Ge detectors)
- High efficiency beta-ray detectors  
(DSSSD: WAS3ABi)

## Collaboration and Future

- Proposals, manpower, detectors

A lots of new results are coming from RIBF.



# EURICA 2012 U-beam Campaign



Name	Institute	Name	Institute
NISHIMURA Shunji	RIKEN	SIMPSON Gary	Grenoble
LORUSSO Giuseppe	RIKEN	NISHIBATA Hiroki	Osaka Univ.
WATANABE Hiroshi	Beihang Univ.	KWON Young Kwan 권영관	IBS
SUMIKAMA Toshiyuki	Tohoku Univ.	SAHIN Eda	Univ. of Oslo
DOORNENBAL Pieter	RIKEN	ODAHARA Atsuko	Osaka Univ.
XU Zhengyu	Univ. of Tokyo/RIKEN	NIIKURA Megumi	Univ. of Tokyo
ISOBE Tada-aki	RIKEN	MATSUI Keishi	Univ. of Tokyo
SöderSTRÖM P.A.	RIKEN	CHEORGHE I. Stefan	IPN Orsay
JUNG Hyo-Soon 정효순	Chung-Ang Univ.	JOHN Philipp	Universita degli Studi di Padova
BROWNE Frank	Brighton Univ./IPA	MENGONI Daniele	Universita degli Studi di Padova
TAPROGGE Jan	Univ. Madrid/IPA	ORLANDI Riccardo	Leuven
VAJTA Zsolt	Univ. Debrecen/IPA	CHAE Kyung Yuk	SKKU
GEY Guillaume	Univ. Joseph Fourier	NAPOLI Daniel R.	INFN
WU Jin	Peking Univ./RIKEN	BENZONI Giovanna	INFN
YAGI Ayumi	Osaka Univ.	LANE Gregory	ANU
LI Zhihuan	Peking Univ.	MOSCHNER Kevin	Univ. of Koeln
YOSHINAGA Keta	Tokyo Univ. of Science	MONTANER Piza Ana	Istituto de Fisica
BABA Hidetada	RIKEN	KOEHLER Katrina	--
SAKURAI Hiroyoshi	Univ. of Tokyo	PODOLYAK Zsolt	Surrey Univ.
SHIMODA Tadashi	Osaka Univ.	PATEL Z	Surrey Univ.
KIM Yong-Kyun	IBS	KONDEV Philipp	ANL
KIM Gi Dong	IBS	NAQVI Farheen	Yale Univ.
KWON Young Kwan 권영관	IBS	CRESPI Fabio	Milano?
SCHAFFNER Henning	GSI	MOON ?ChangBum	Hoseo Univ.
KOJOUHAROV Ivan	GSI	GERNHAEUSER Roman	TU Muenchen
KURZ Nick	GSI	STEIGER Konrad	TU Muenchen
		FAMIANO Michael	West Michigan Univ.
		JUNGC LAUS Andrea	Univ. Madrid
		KROLL Thorsten	Tech. Univ. Darmstadt
		ILIEVA Stoyanka	Tech. Univ. Darmstadt
		BONIG Sabine Esther	Tech. Univ. Darmstadt
		WENDT Andreas	Univ. of Cologne
		DROUET Floriane	Lab. de Phys. Subatomique

Thank you.