Decay spectroscopy of exotic nuclei at RIBF

Shunji NISHIMURA

(RIKEN Nishina Center)

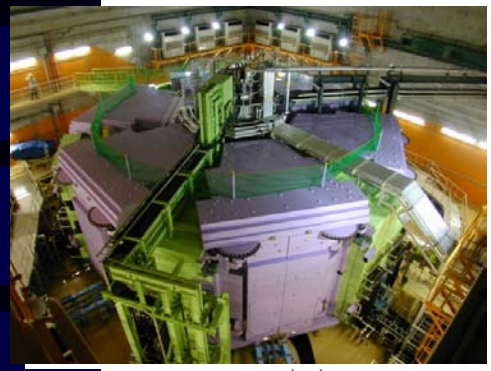
EURICA

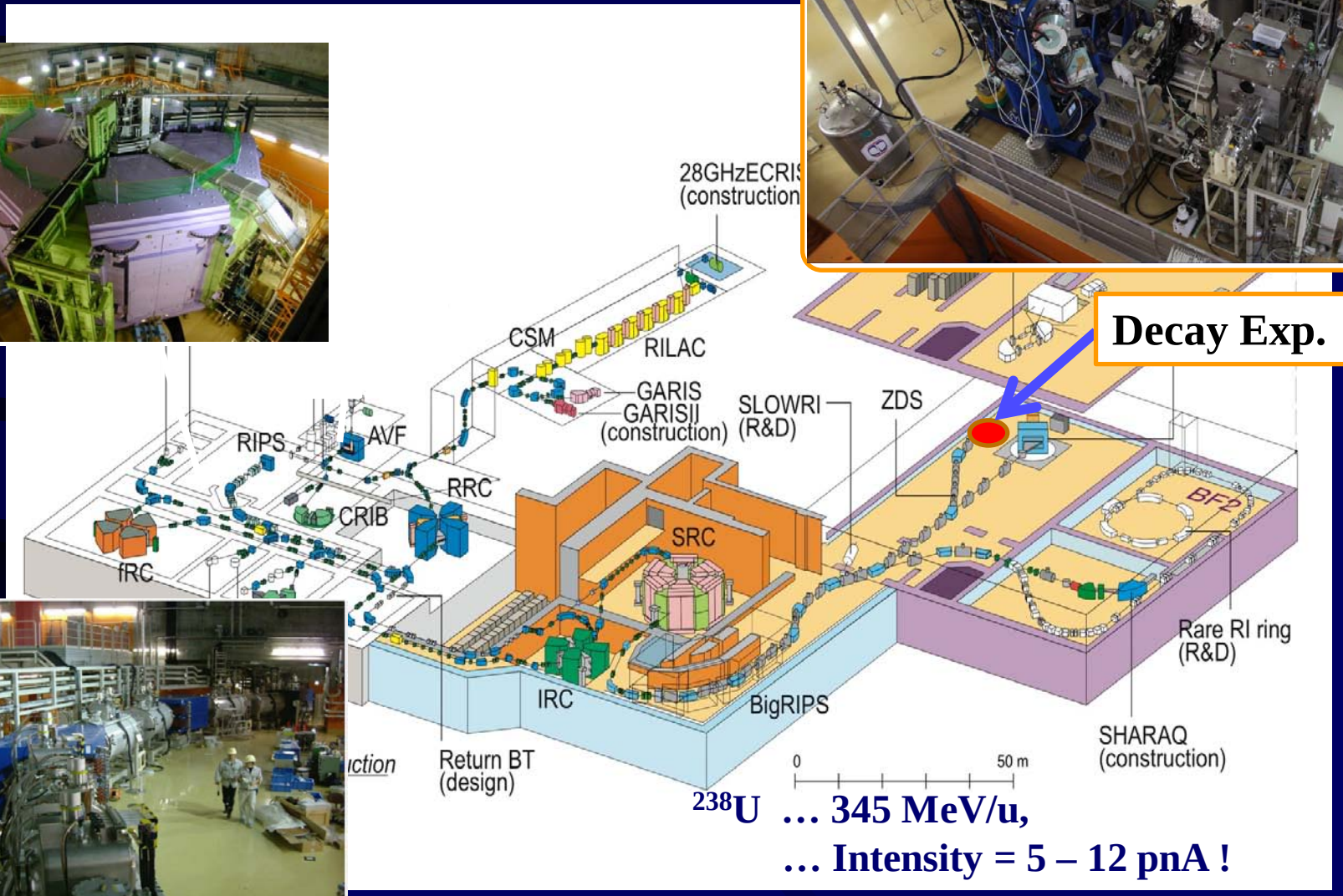
- ^{78}Ni (Z=28,N=50)
  … Double magic nuclei !?

- ^{132}Sn (Z=50, N=82) region
  ^{128}Pd (N=82)
  $^{136\text{-}138}$Sn

Consistent with shell model prediction!?

Location of Decay Station





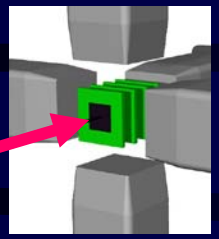
^{238}U … 345 MeV/u,

… Intensity = 5 – 12 pnA !

Decay Programs at RIBF

2009
2010
2011
2012
2013
2014

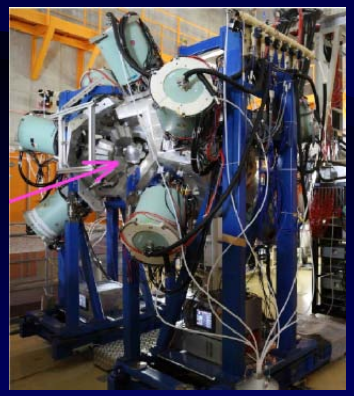
β-γ



^{110}Zr region
(3-days)

*PLB 696, 186 (2011)
*PRL. 106, 052502 (2011)
*PRL. 106, 202501 (2011)
*PLB 704, 270 (2011)

EURICA Project

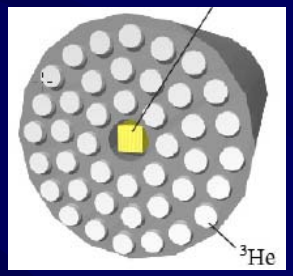


WAS3ABi (Si)

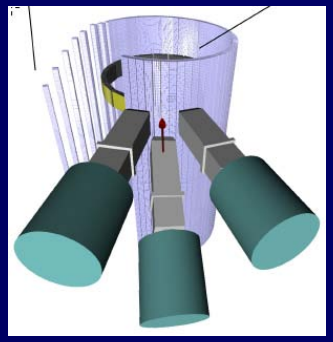
β-n
[high efficiency]

^{3}He counters (x 27)

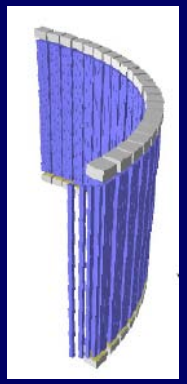
Neutron detectors



β-γ-n
[fast timing]



Neutron detectors
(TOF)
LaBr3 detectors



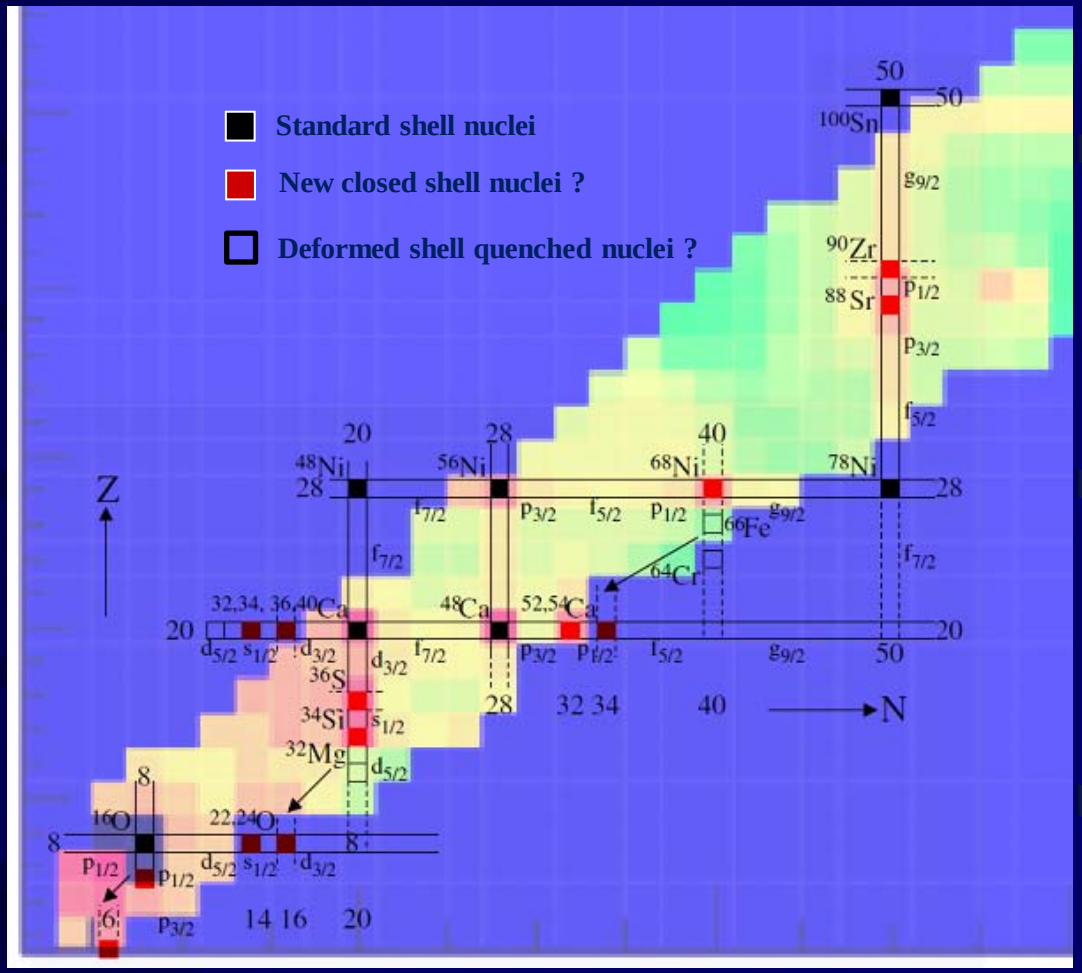
Motivation (Decay Spectroscopy)

Measurements by decay exp.

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

Systematic Study

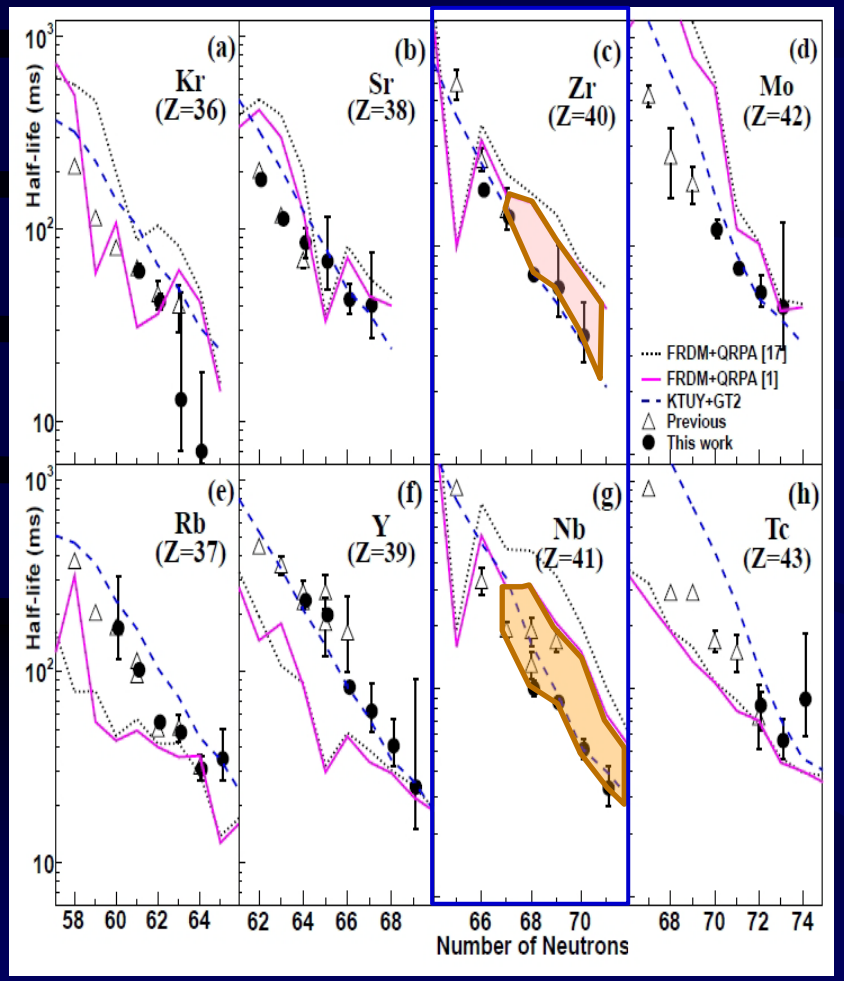
- Nuclear Structure
  - **New magic number ?**
  - **Disappearance?**
  - **Shell quenching?**
  - **Deformation?**

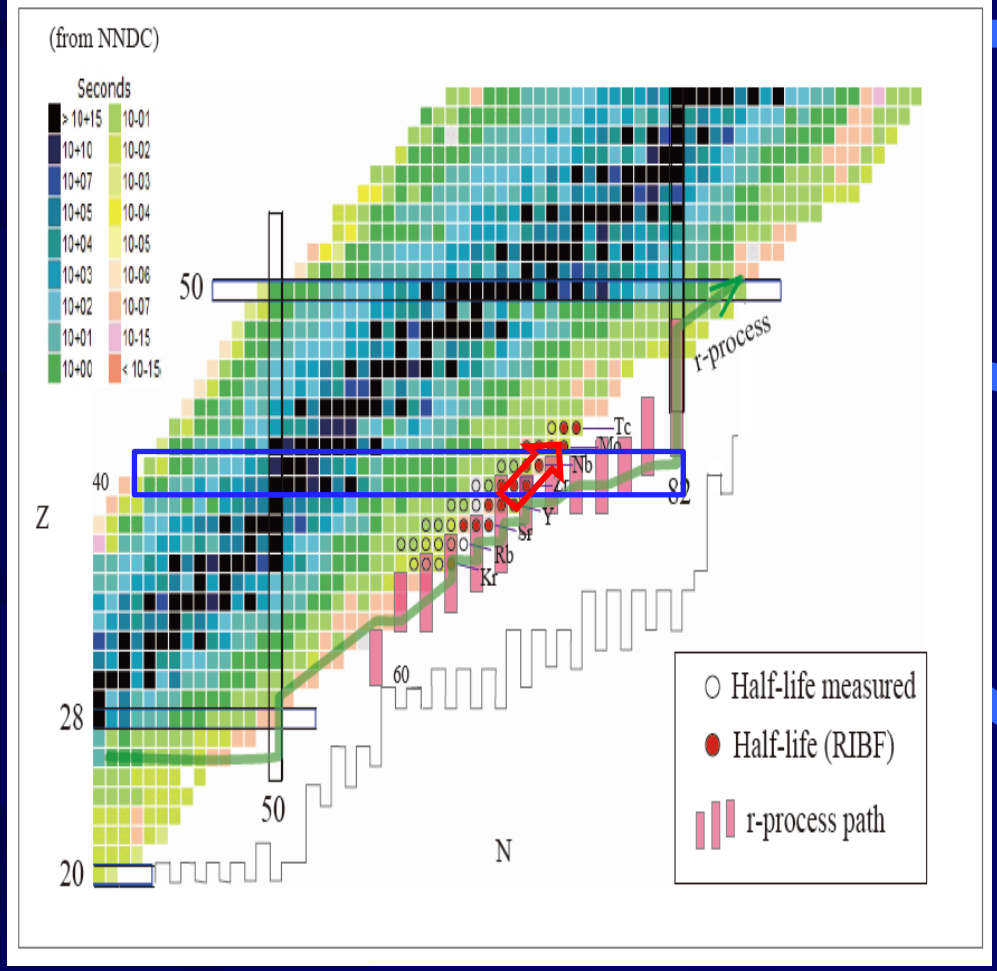


Inputs

- **Feedback to Nuclear Theory**
- **Study of Nuclear Astrophysics**

Decay Experiment in 2009

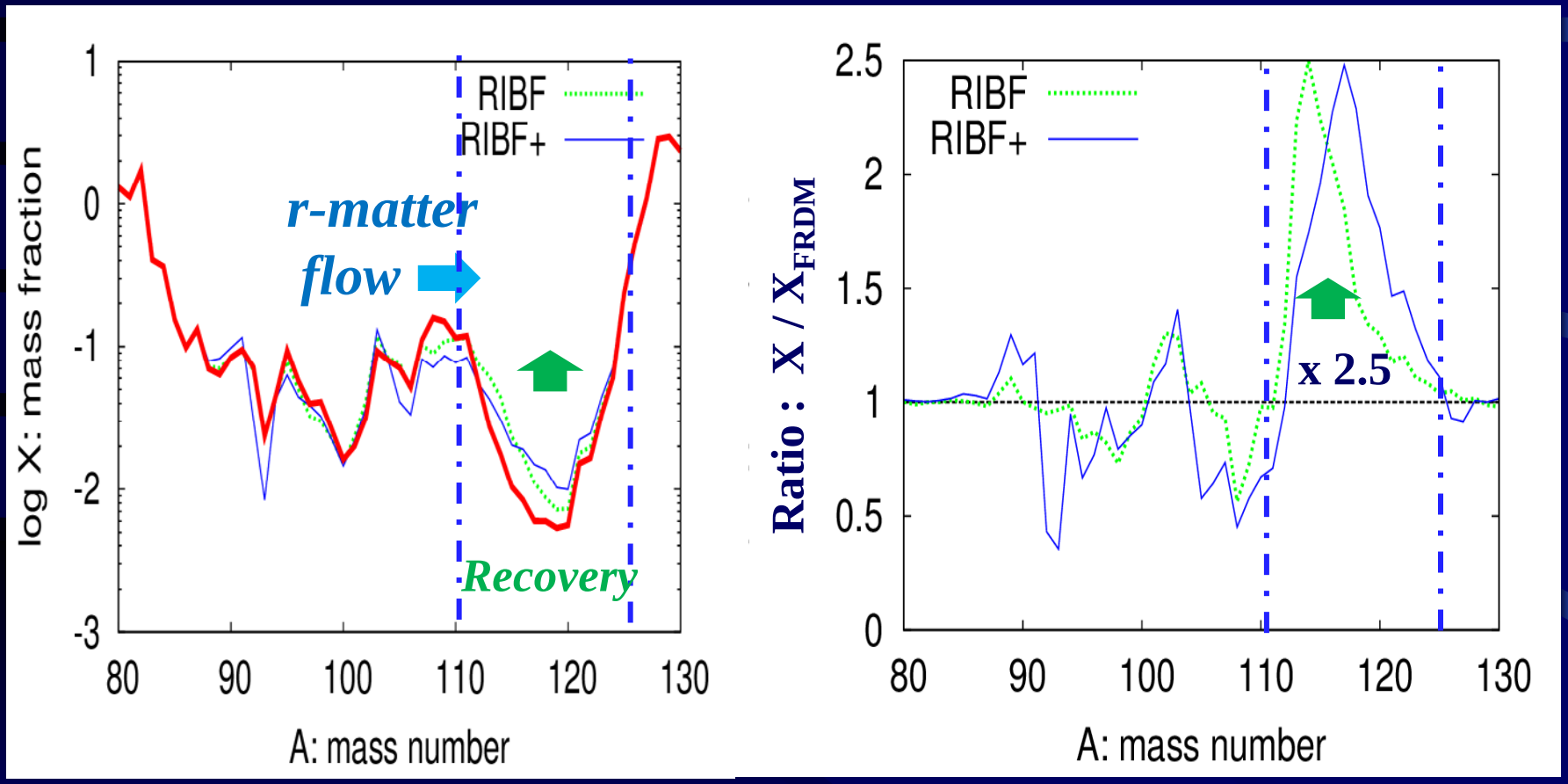




Zr and Nb decay faster than expected by FRDM+QRPA ($T_{1/2}$: 1/2 ~ 1/3)

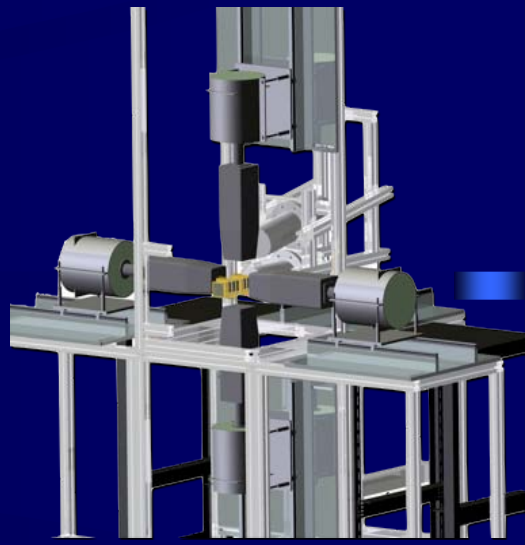
RIBF data → Impact to r-process abundance

Nobuya Nishimura, T.Kajino, G.Mathew, SN, T.Suzuki, PRC 85 (2012)



The calculated r-process abundance is improved by factor of x 2.5.
But, there is still issue remaining in mass A=110 – 125!

Upgrade : 2009 → 2012



U-beam intensity

- 0.2 pnA → ~ 10 pnA … x 50 times

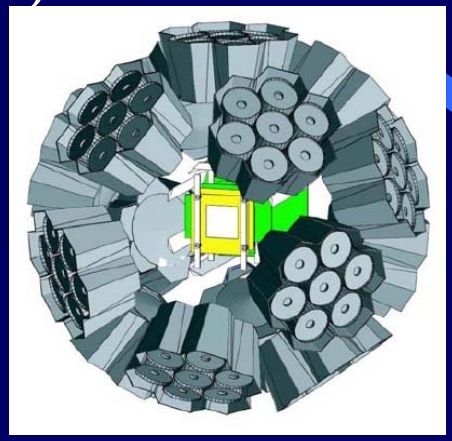
Gamma-ray detector

- 4 Clover detectors

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

… x 10 times

(→ gamma-gamma coincidence … x 100 times)



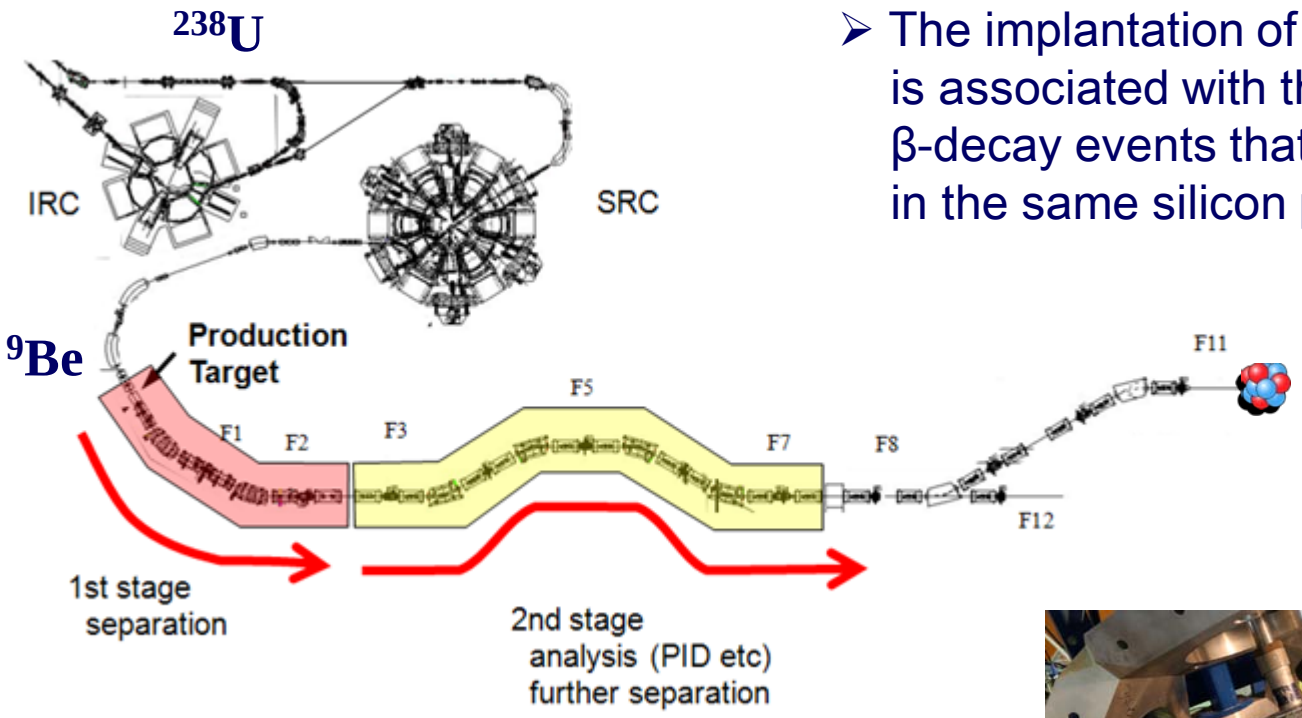
Beta counting system

- 16 x 16 pixels x 7 layers = 1792 pixels

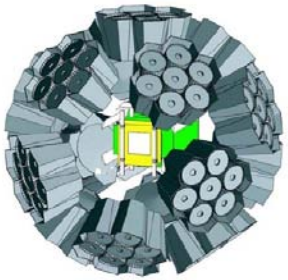
→ 40x60 pixels x 8 layers = 19200 pixels

… x 10 times

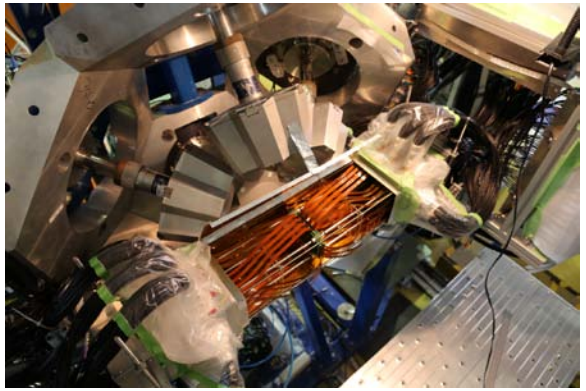
Beam Production at RIBF



- The implantation of an identified RI is associated with the following β-decay events that are detected in the same silicon pixel (DSSSD).

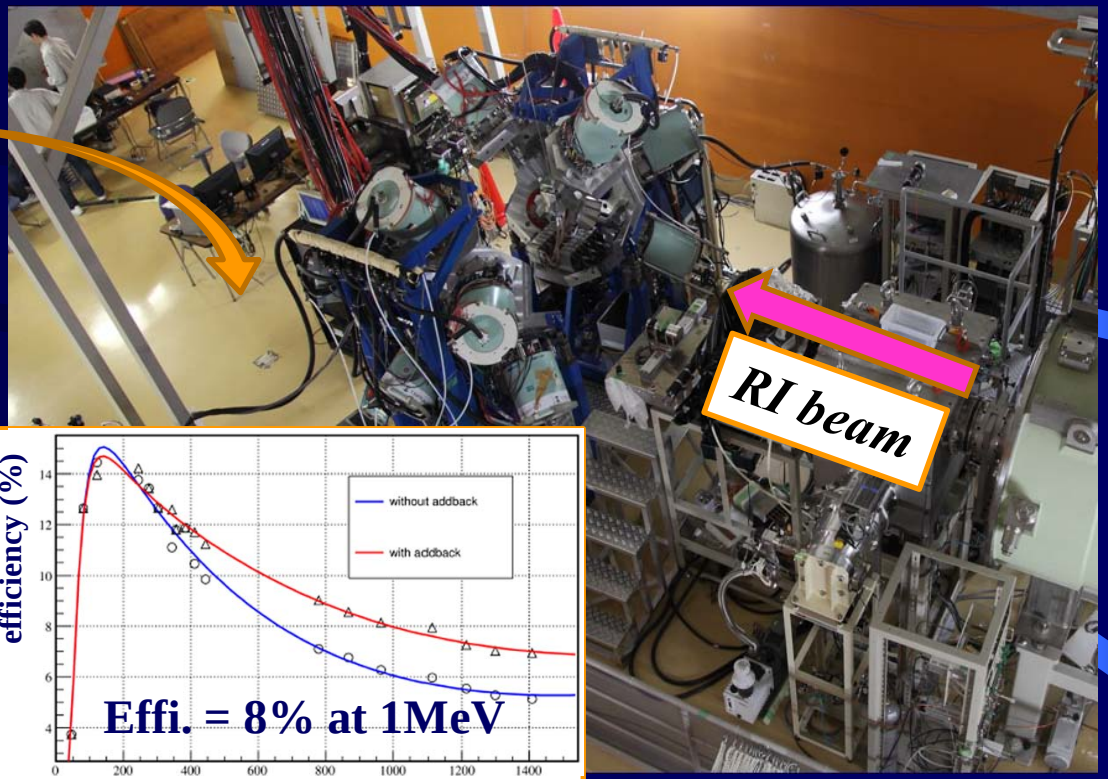


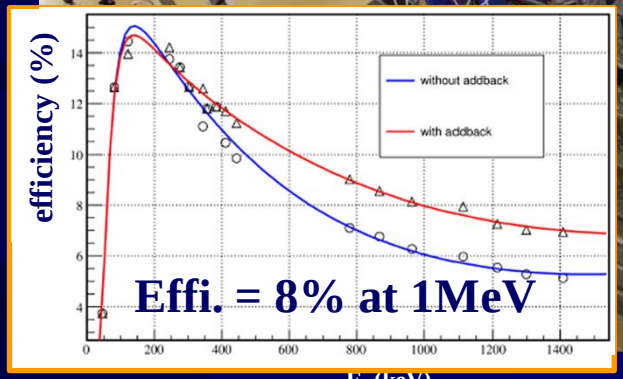
- ΔE-TOF-Bρ method using the focal plane detectors.



EURICA Project at RIBF

(EUROBALL RIKEN Cluster Array)





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

RIKEN RIBF (Japan)

Installation completed in 2012 Feb.

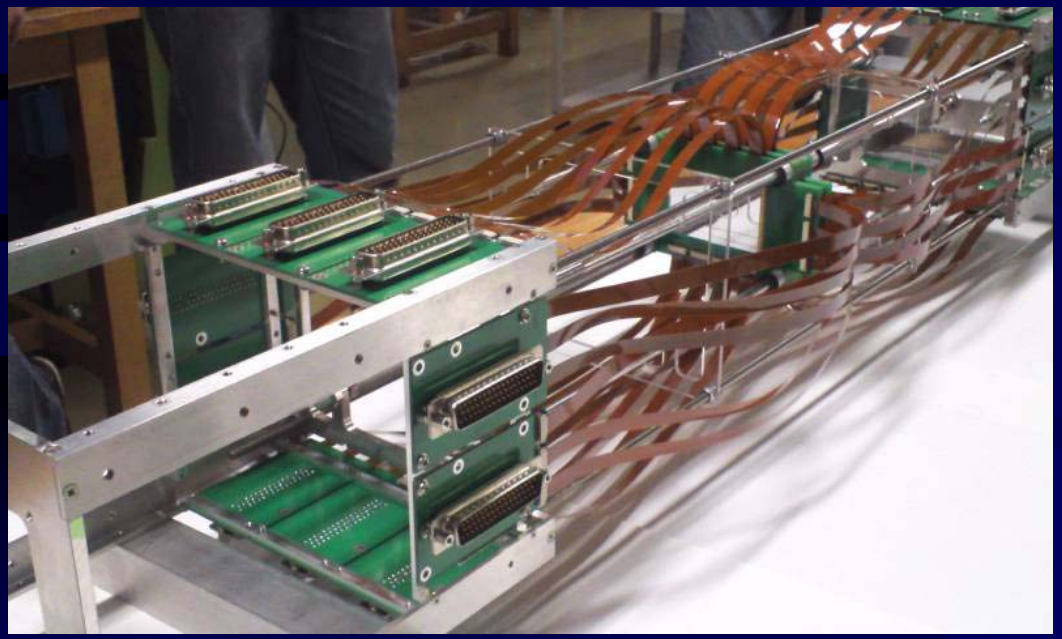
New Beta Counting System : WAS3ABi

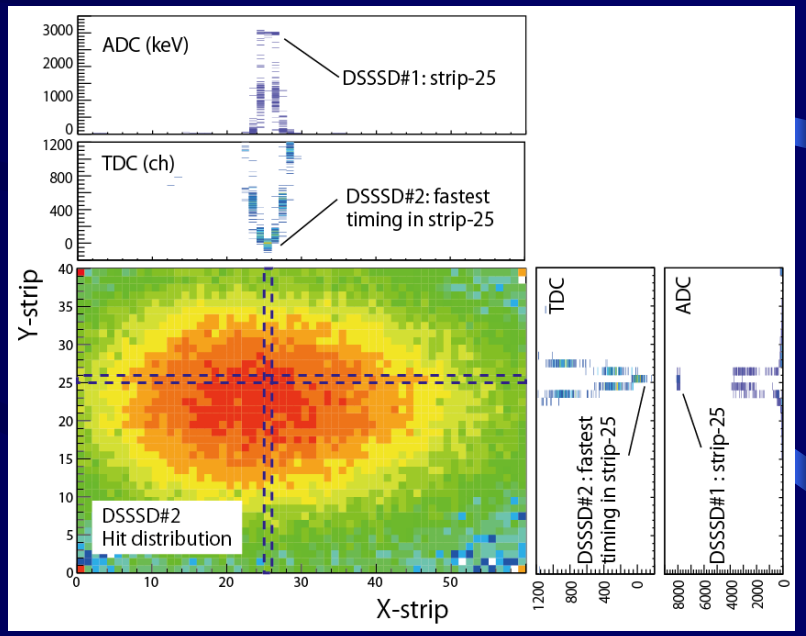
(Wide-range Active Silicon-Strip Stopper Array for Beta and ion detection)

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

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

Timing information is also used for reconstruction of hit position.

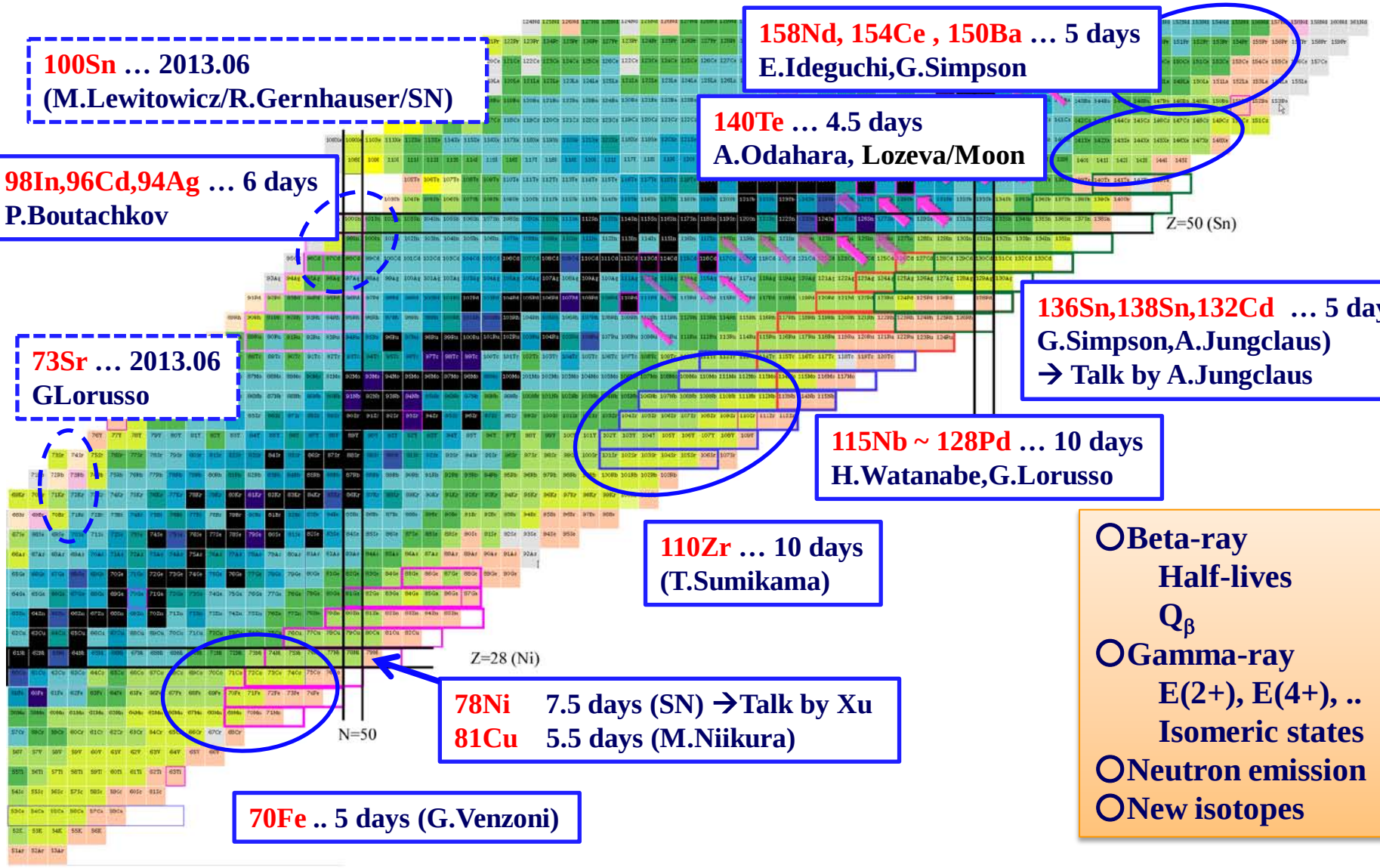




Options:

- Qbeta calorimeter in 2012.
- Fast timing plastic scintillation detectors in 2013

Survey of Decay Properties with EURICA



100Sn … 2013.06
(M.Lewitowicz/R.Gernhauser/SN)

158Nd, 154Ce , 150Ba … 5 days
E.Ideguchi,G.Simpson

140Te … 4.5 days
A.Odahara, Lozeva/Moon

98In,96Cd,94Ag … 6 days
P.Boutachkov

136Sn,138Sn,132Cd … 5 days
G.Simpson,A.Jungclaus)
→ Talk by A.Jungclaus

73Sr … 2013.06
GLorusso

115Nb ~ 128Pd … 10 days
H.Watanabe,G.Lorusso

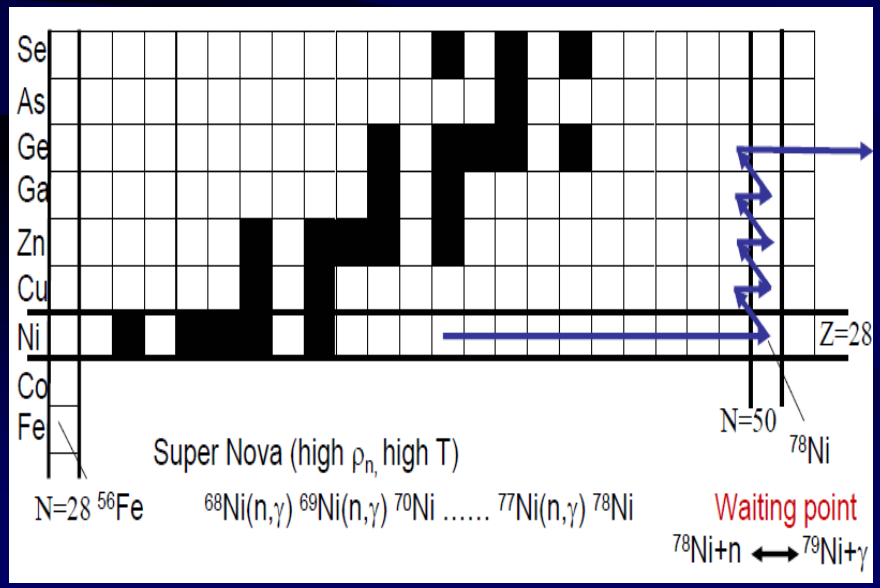
110Zr … 10 days
(T.Sumikama)

- Beta-ray
  - Half-lives
  - Q_β
- Gamma-ray
  - E(2+), E(4+), ..
  - Isomeric states
- Neutron emission
- New isotopes

78Ni 7.5 days (SN) →Talk by Xu
81Cu 5.5 days (M.Niikura)

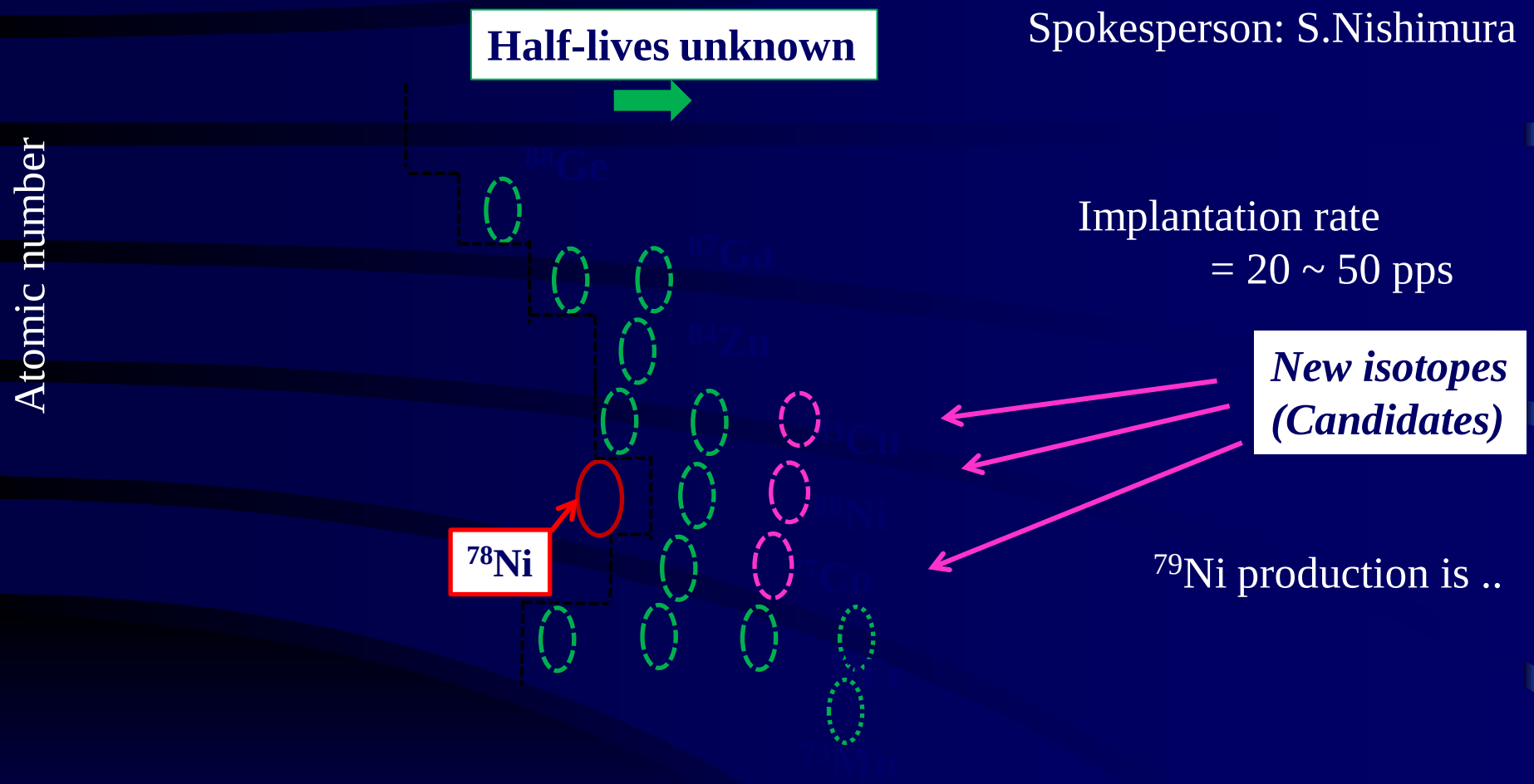
70Fe .. 5 days (G.Venzoni)

Decay Spectroscopy in the vicinity of double magic ^{78}Ni (Z=28, N=50)



Beam production around ^{78}Ni region

Spokesperson: S.Nishimura

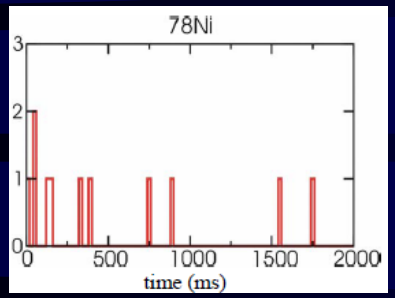


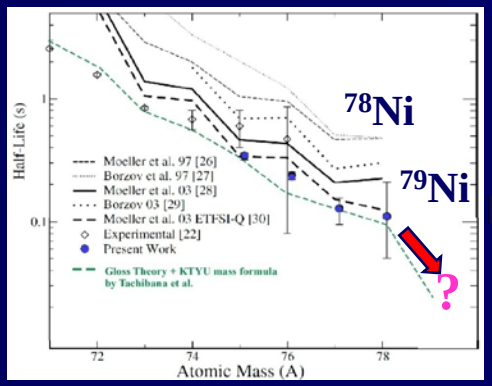
Additional experiment around ^{81}Cu data (Niikura exp.)

→ ~ 10 k of ^{78}Ni produced in total.

^{78}Ni beta-decay half-life

Hosmer (MSU)
PRL (2006)





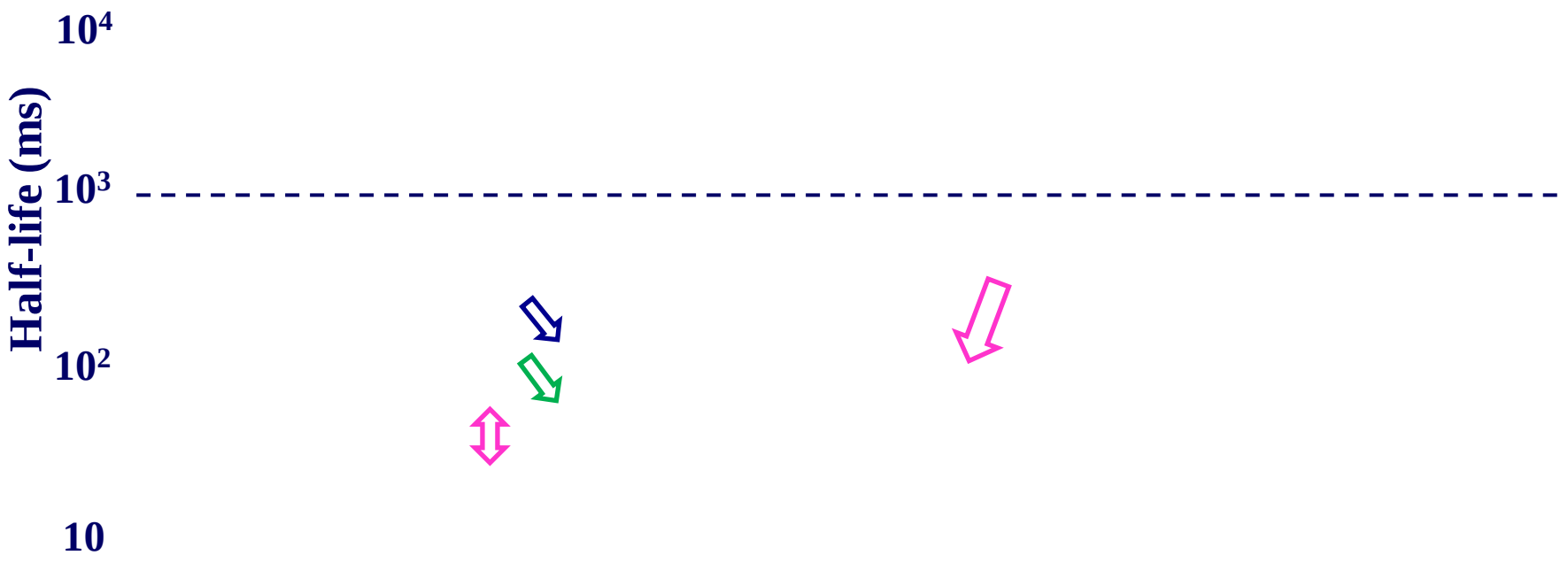
Decay spectra obtained in WAS3ABi and with EURICA.
What about N=51 (^{79}Ni)? Z=27 (^{77}Co)?

Systematic study of $T_{1/2}$ around ^{78}Ni (Z=28,N=50)

FRDM overestimates the half-lives of r-process isotopes (Zn, Ga, and Ge).

Compilation of Half-lives around ^{78}Ni

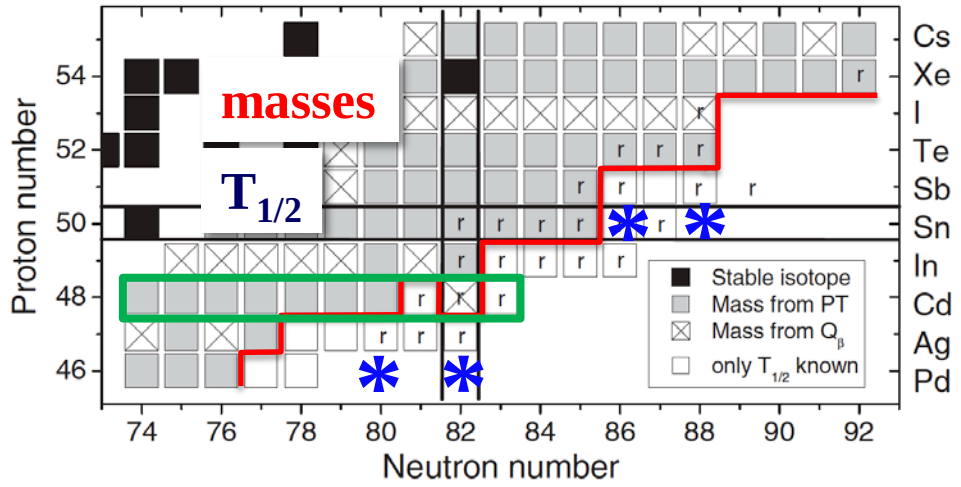
Z.Xu PhD



Our results indicate ^{78}Ni is double magic nuclei !?

→ More results from gamma-ray spectroscopy (EURICA)

Decay properties around double magic ^{132}Sn (Z=50, N=82)



J. Hakala et al., Phys. Rev. Lett. 109 (2012) 032501

New isomers around 132Sn region

Half-lives of Cd isotopes

$^{136\text{-}138}$Sn Region

Spokespersons:
G.Simpson /A.Jungclaus/Gadea

Unknown $T_{1/2}$

875.000 ions

^{136}Sn

Very short $T_{1/2}$!

^{138}Sn

5.000 ions

- 136Sn, 138Sn isomers
- A milisecond γ-decaying high-spin trap in ^{129}Cd

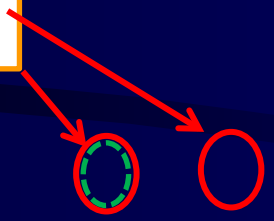
G. Simpson, G.Gey, A.J .,. submitted to Phys. Rev. Lett.

Decay Spectroscopy around ^{128}Pd and ^{115}Nb

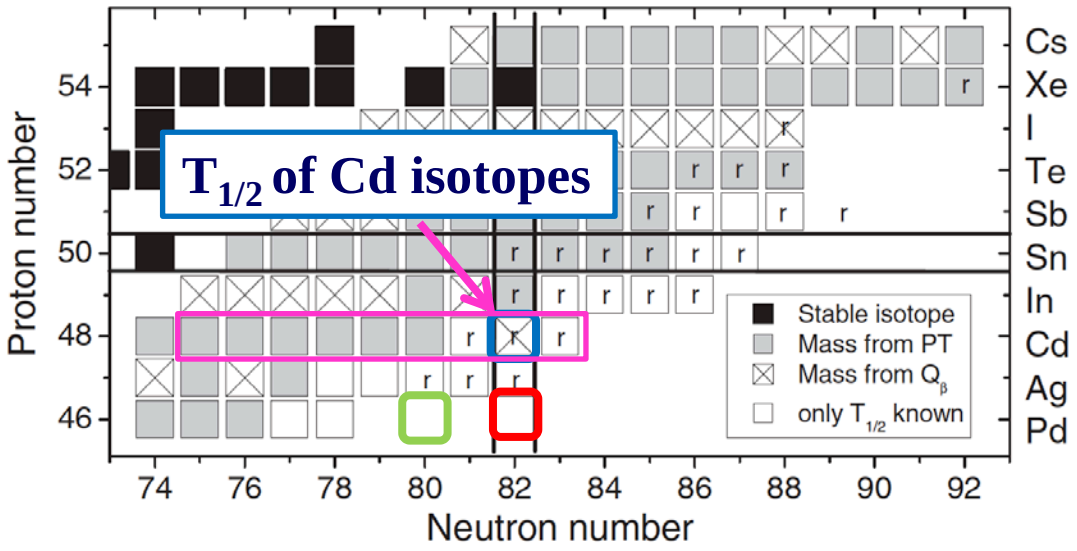
New Isotopes

Spokespersons: H.Watanabe/G.Lorusso

New isomers in ^{126}Pd, ^{128}Pd!

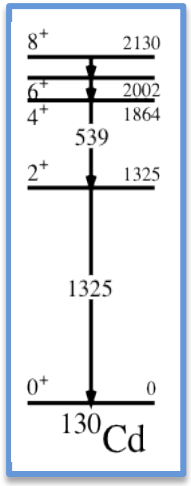


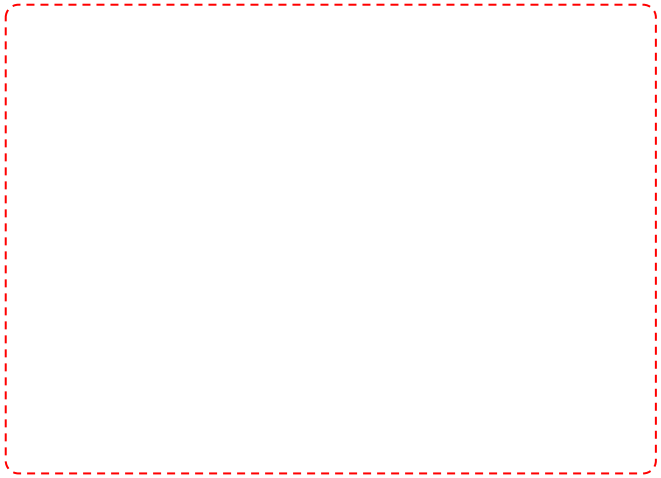
Most Neutron-Rich N=82 Isomer with EURICA
(r-Process waiting point)

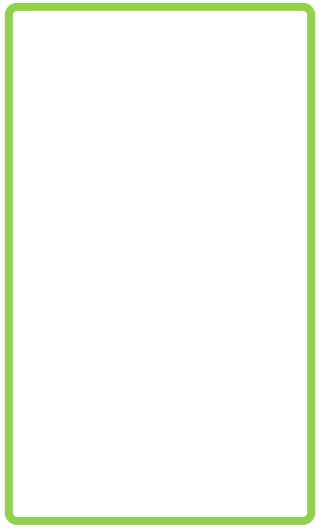


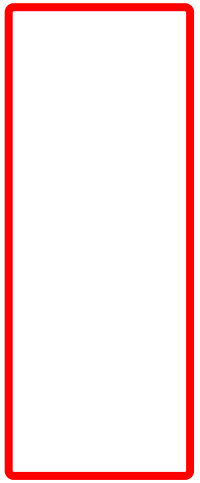
A.Jungclaus, PRL99, (2007)

No evidence for shell quenching



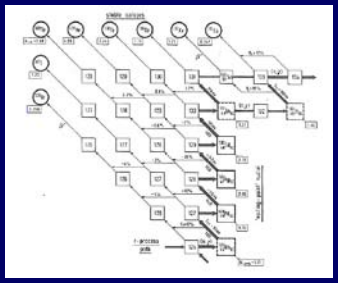






→ No evidence of shell-quenching ….

Systematic of beta-decay half-lives for Cd isotopes



G.Lorusso

Pinedo & Langanke PRL 83 4502 (1999)

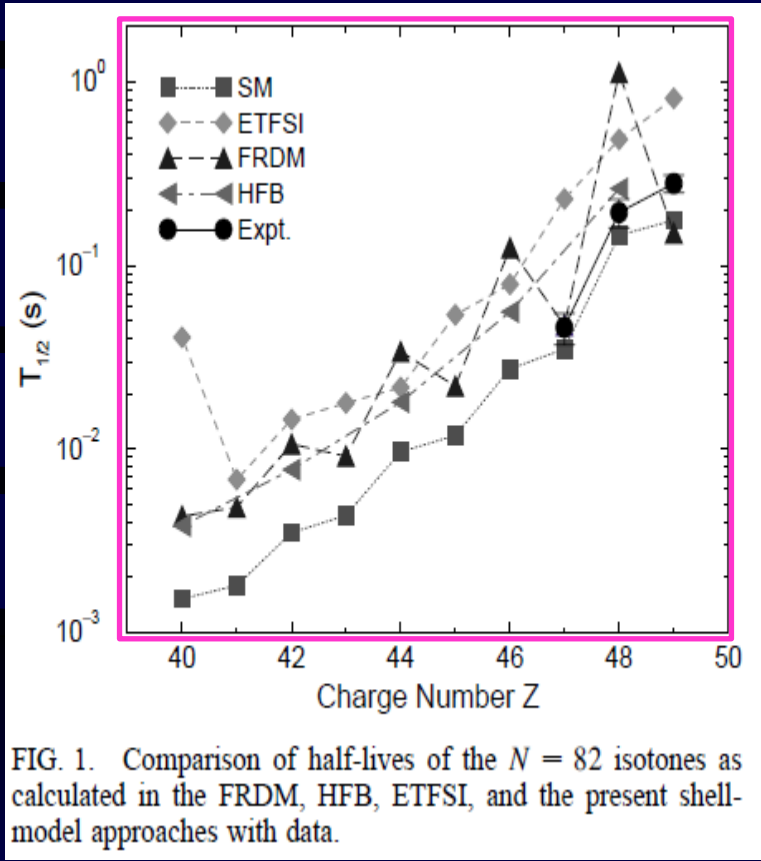


FIG. 1. Comparison of half-lives of the $N = 82$ isotones as calculated in the FRDM, HFB, ETFSI, and the present shell-model approaches with data.

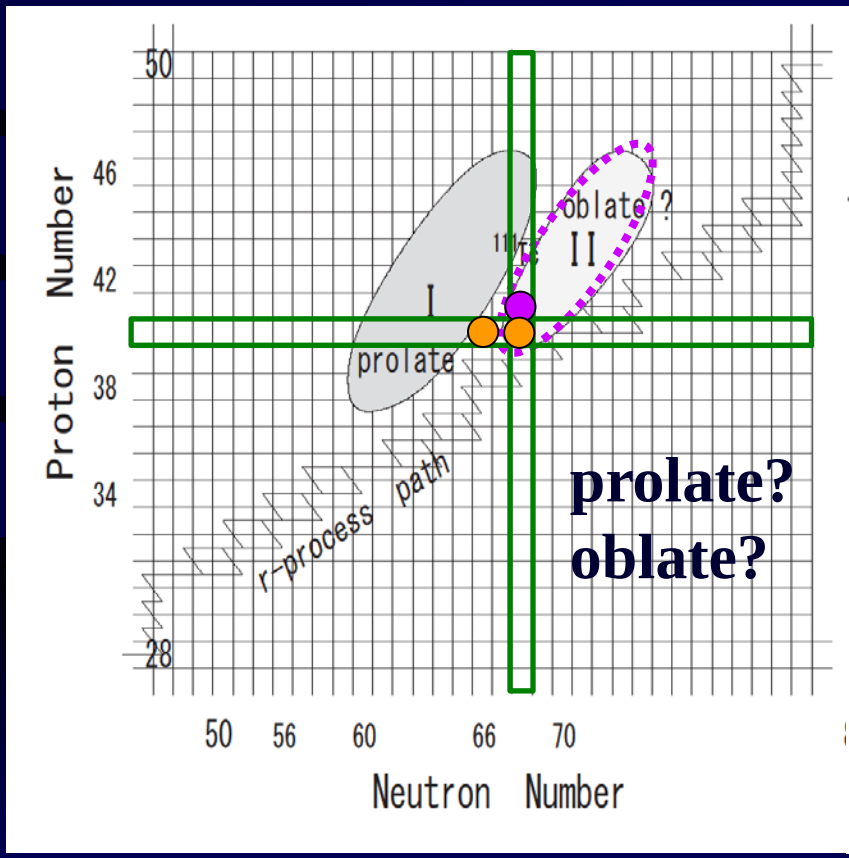
Mid-shell region

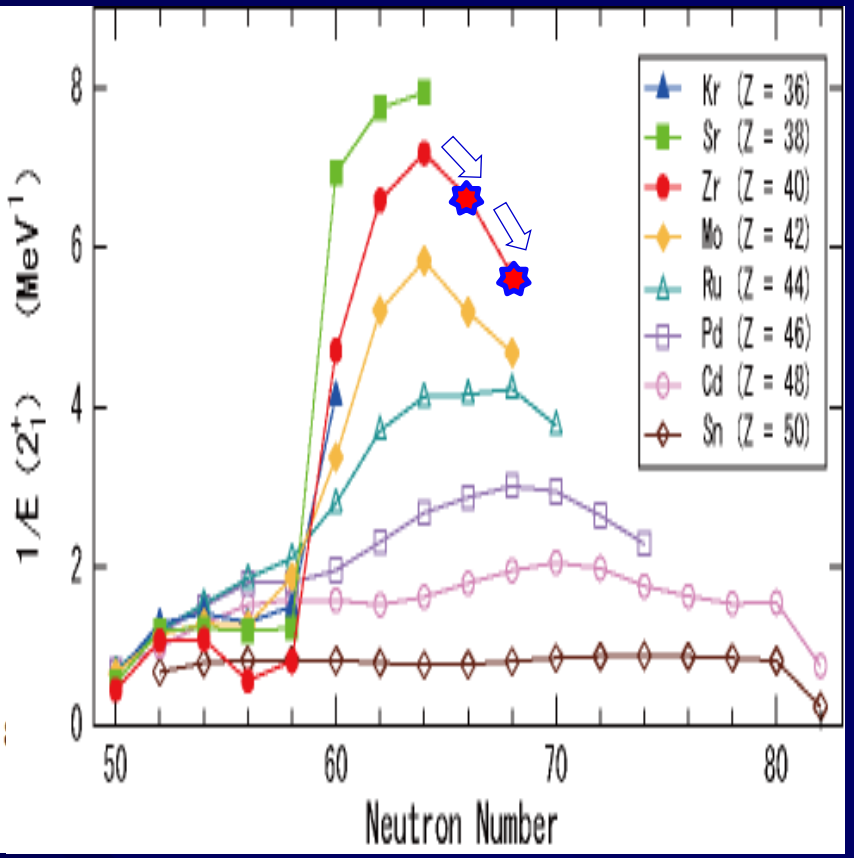
(2013 May)

Deformation

- Phys. Lett. B 696 (2011) H.Watanabe
  Oblate shape isomer for ^{109}Nb?
- Phys. Rev. Lett. 106, 202501 (2011) T.Sumikama
  Structural Evolution : 106Zr and 108Zr

W.Urban, et al., EPJA 20 (2004), EPJA24 (2005)





- Beta-delayed gamma : ^{106}Y → ^{106}Zr
- Isomeric states : ^{108}Zr

Deformed sub-shell closure at N=64 ?

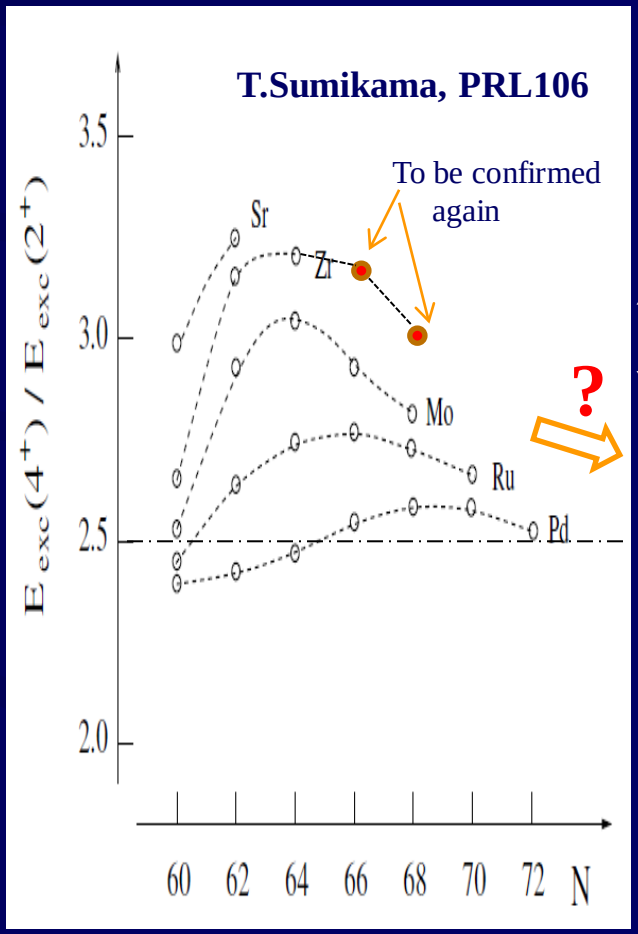
Shape evolution in $^{116, 118}$Ru

Spokesperson: G.Lorusso,H,Watanabe

^{116}Tc Beta-decay
→ ^{116}Ru

^{118}Tc Beta-decay
→ ^{118}Ru

P.-A. Söderström, et al.
Submitted to Phys. Rev. C

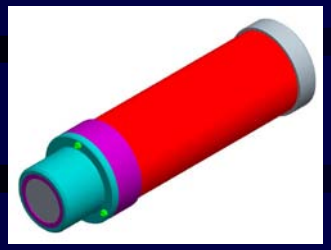


Urban, EPJ A 20, 381 (2004)

Analysis is in progress in other isotopes around ^{110}Zr region

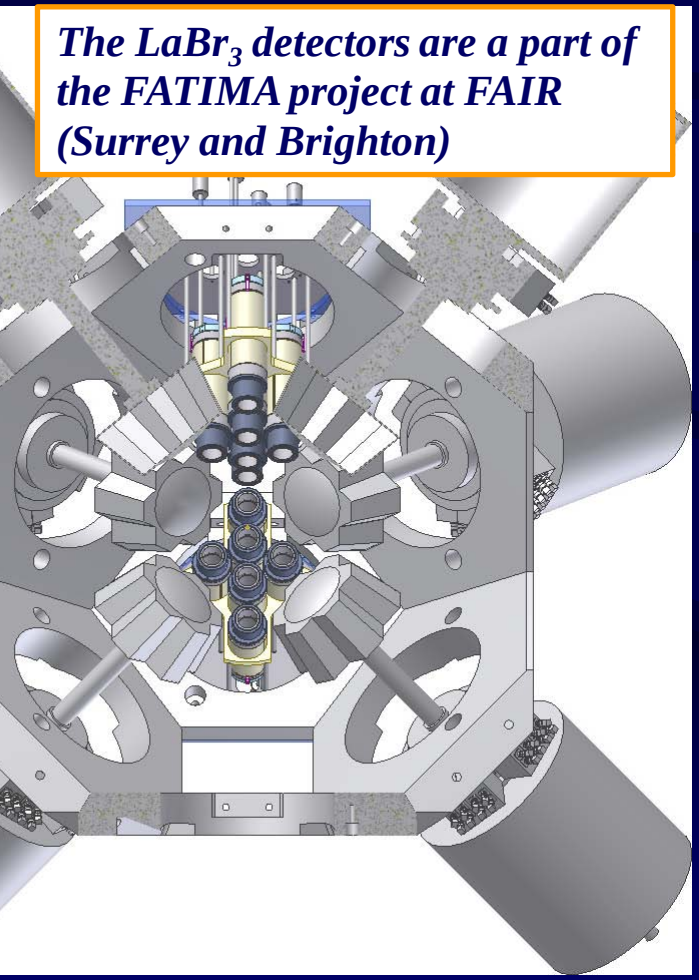
Complementary $LaBr_3$ array for fast timing with EURICA

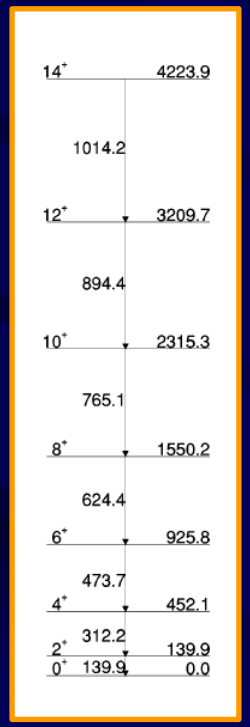
18 detectors
φ1.5” x 2”



- For short life−times a $LaBr_3$ array for fast timing has been installed to complement the HPGe detectors

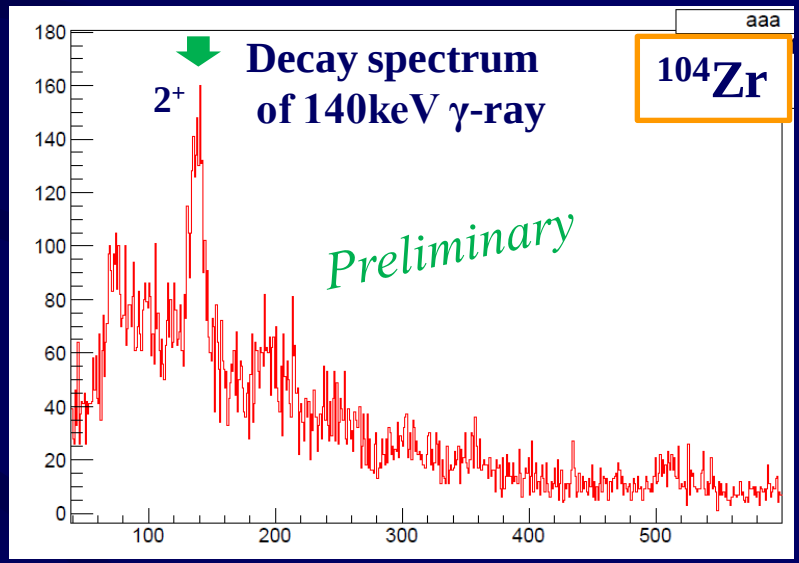
The $LaBr_3$ detectors are a part of the FATIMA project at FAIR (Surrey and Brighton)





^{104}Y beta-decay is used as start.

Beta-decay of ^{104}Y → ^{104}Zr

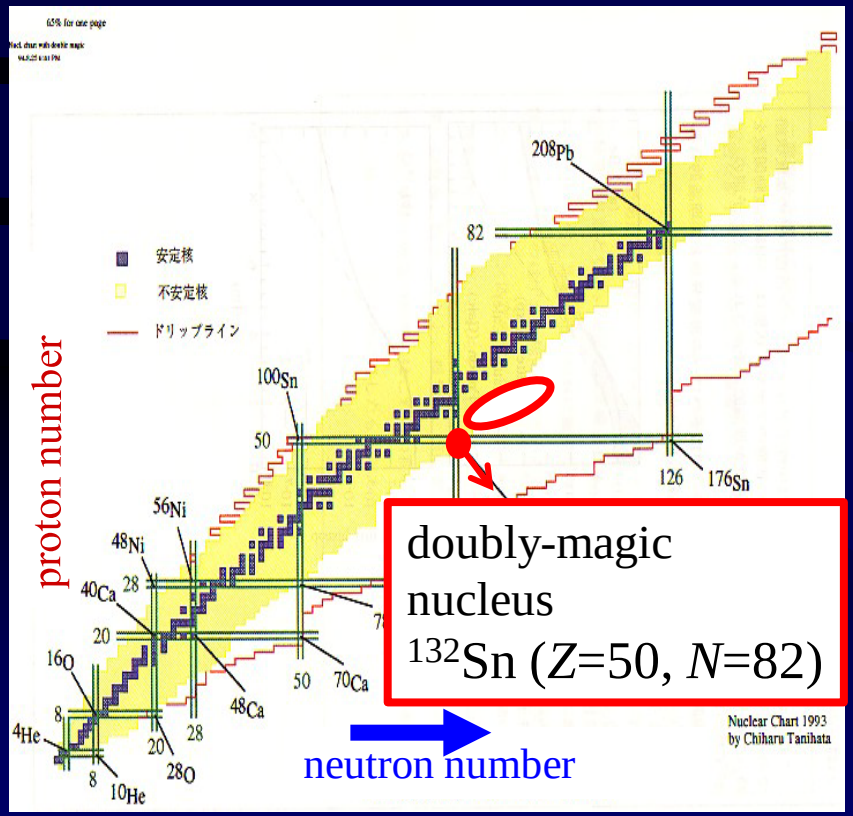


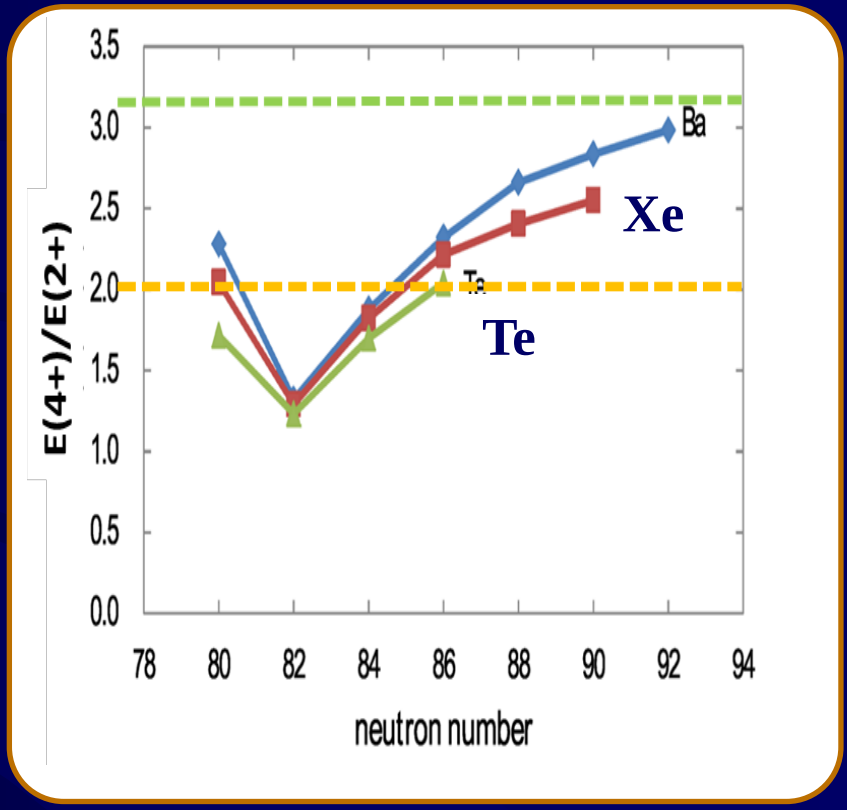
^{106,108}Zr

→ T.Sumikama, F.Browne, A.Bruce

Shape evolution in neutron-rich A~140 nuclei beyond doubly-magic ^{132}Sn

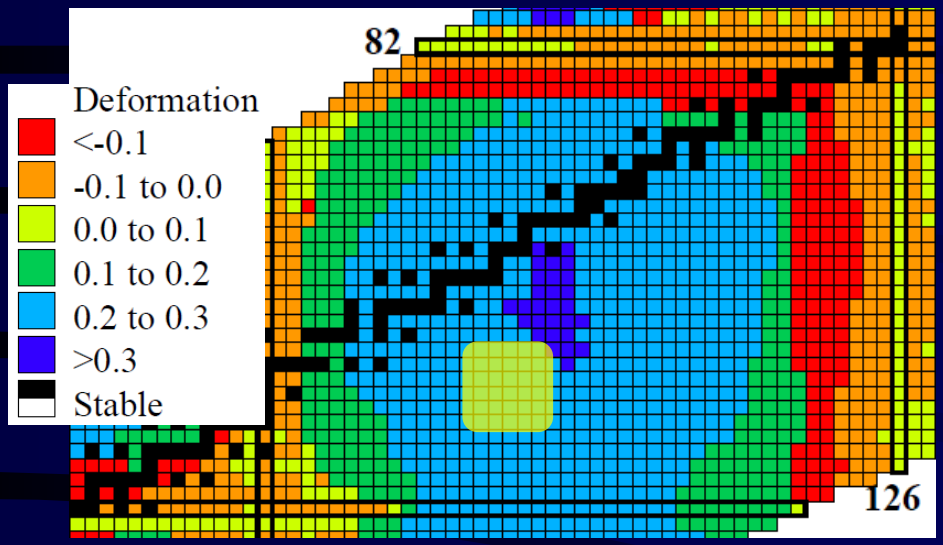
A. Odahara (Osaka),
R. Lozeva (Strasbourg),
C.B. Moon (Hoseo)



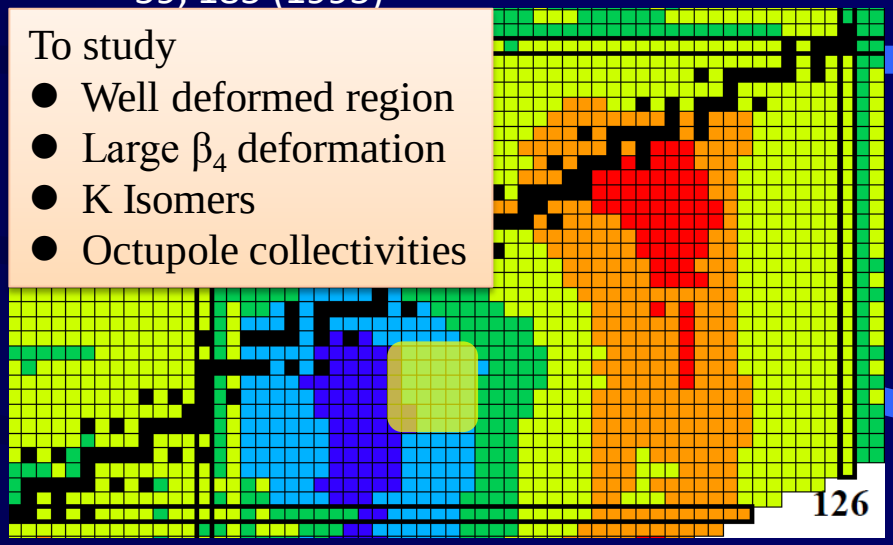


Search for K-isomers (Z ~ 60)

β_2 E.Ideguchi/G.Simpson



β_4 P. Möller et al., At. Data Nuc. Data Tab. 59, 185 (1995)



To study
- Well deformed region
- Large β_4 deformation
- K Isomers
- Octupole collectivities

Isomer and β-γ spectroscopy

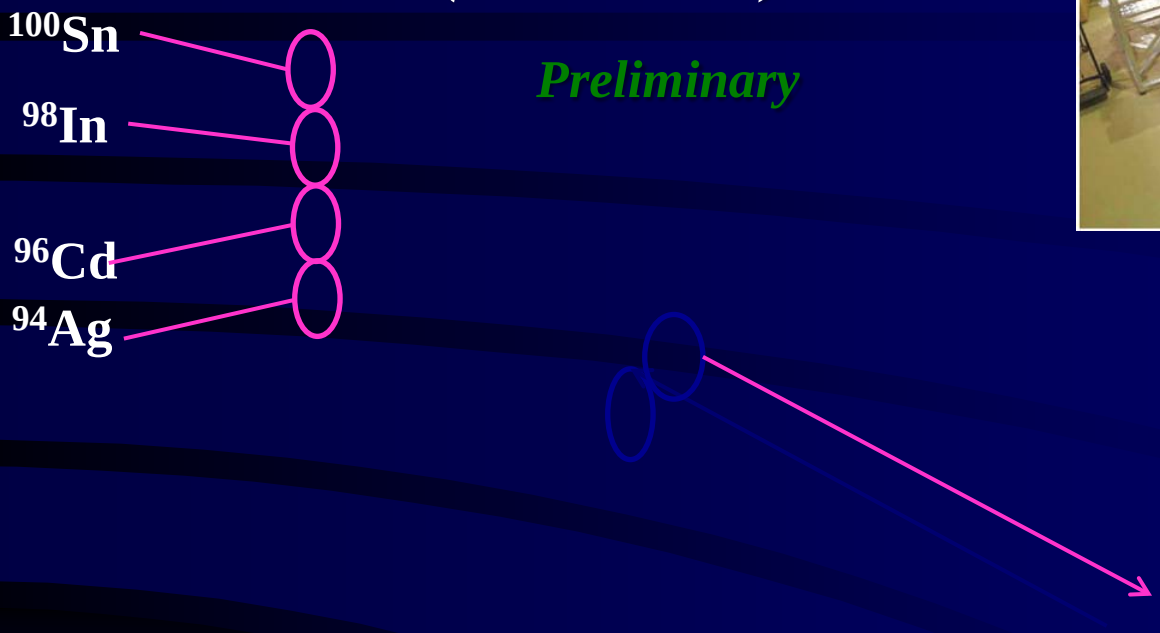
^{156}Nd

Proton-rich Nuclei

^{98}In, ^{96}Cd, ^{94}Ag, ..

RIBF-083 (P.Boutachkov)

Preliminary



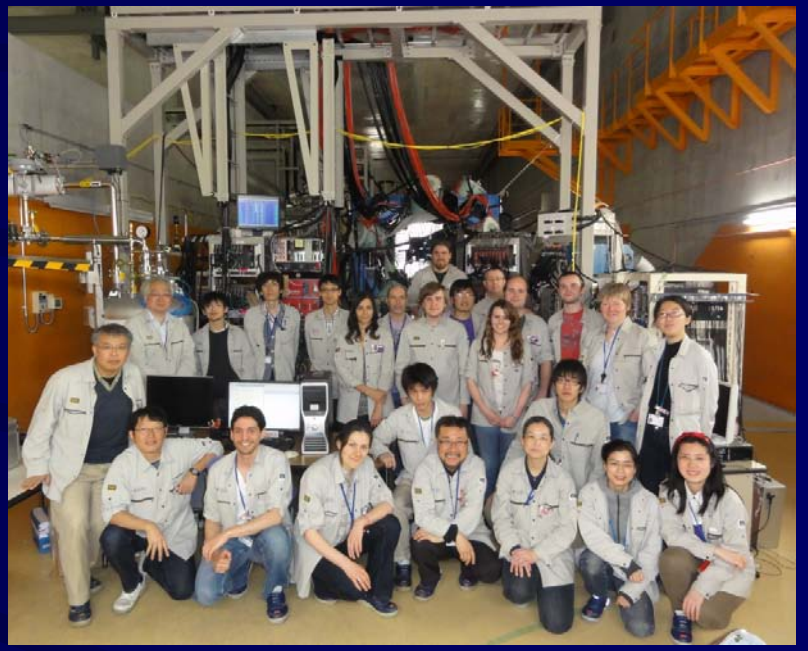
^{96}Pd isomer

^{96}Ag isomer decay:
P. Boutachkov et al.: Phys. Rev. C 84, 044311 (2011)

EURICA U-beam Campaigns

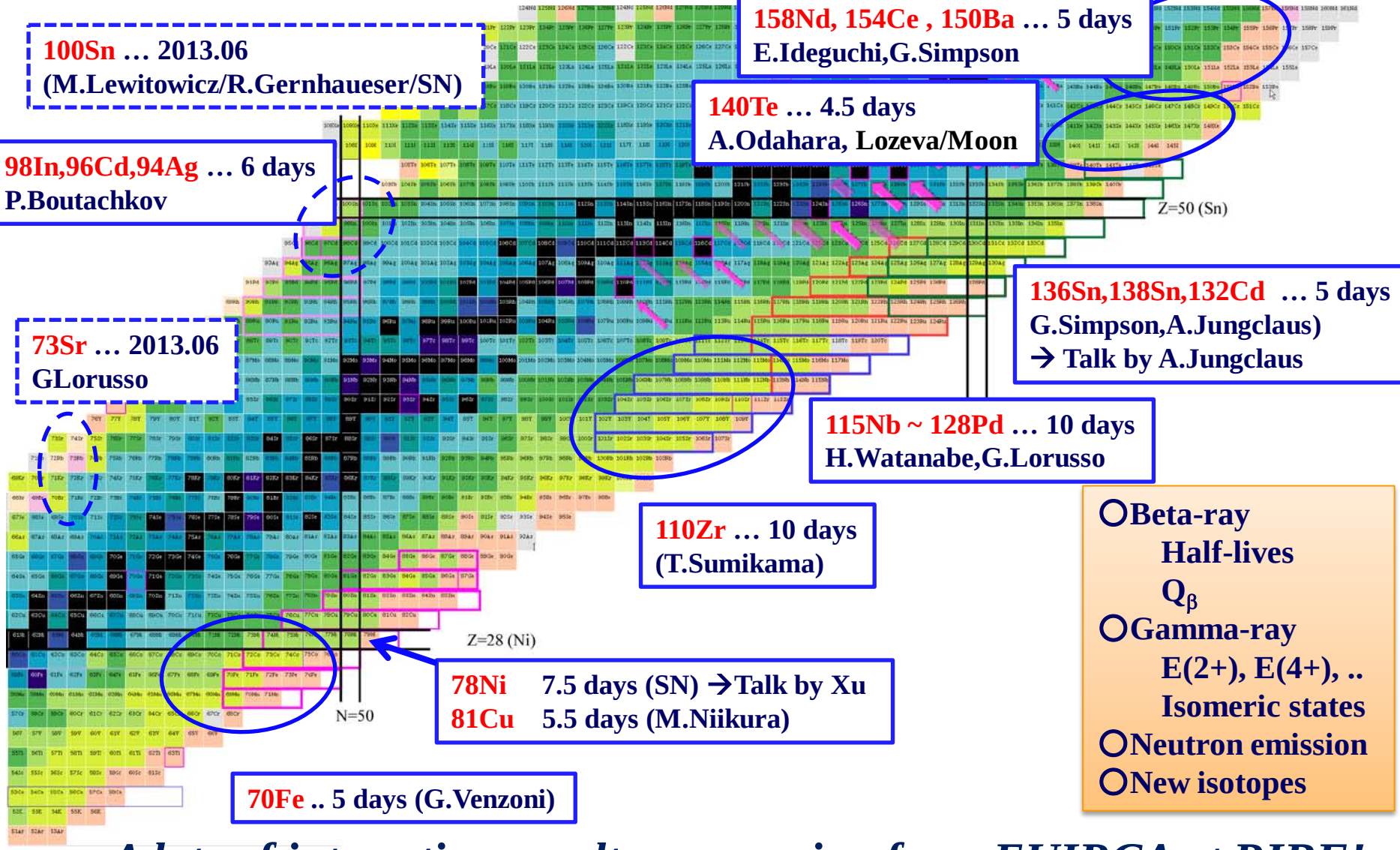
2012 Nov.-Dec.

2013 May



Collaboration:
Tohoku, Univ. Tokyo, Brighton Univ. Debrecen, Joseph Fourier, Osaka Univ. Peking, LPSC, IBS, Oslo, Consejo Sup. De Inv. Cientificas, IPN Orsay, Padova, Leuven, SKKU, INFN, ANU, Koeln, TU Muenchen, Fisica, Legnaro, ATOMKI, INFN-Milano, INFN-Firenze, INFN-LNL, Univ. di Padova, Surrey, GSI, ANL, Yale, Milano, Univ. Madrid, Tech. Univ. Darmstadt, Univ. Istanbul, CNS, CEA, RCNP, Univ. Notre Dame, Inst. voor Kern-en Stralings Fysica, Hoseo Univ., Univ. Tsukuba, Inst. Plurid. Hubert Curien, and RIKEN

SUMMARY



100Sn … 2013.06
(M.Lewitowicz/R.Gernhaueser/SN)

158Nd, 154Ce , 150Ba … 5 days
E.Ideguchi,G.Simpson

140Te … 4.5 days
A.Odahara, Lozeva/Moon

98In,96Cd,94Ag … 6 days
P.Boutachkov

136Sn,138Sn,132Cd … 5 days
G.Simpson,A.Jungclaus)
→ Talk by A.Jungclaus

73Sr … 2013.06
GLorusso

115Nb ~ 128Pd … 10 days
H.Watanabe,G.Lorusso

110Zr … 10 days
(T.Sumikama)

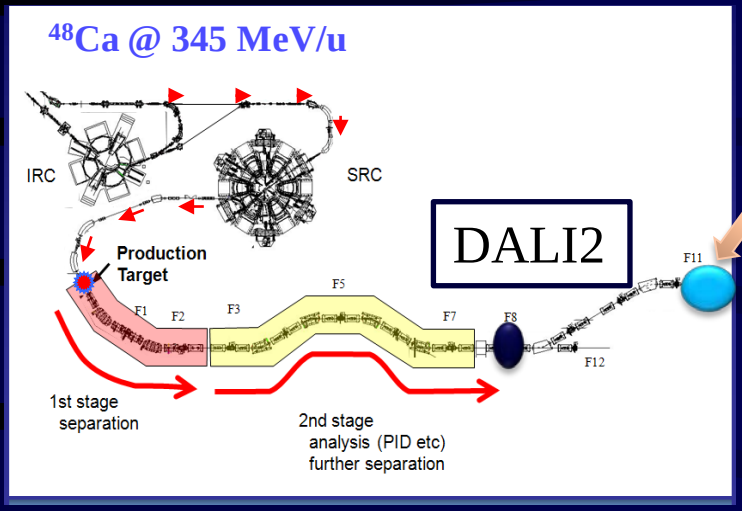
- Beta-ray
  - Half-lives
  - Q_β
- Gamma-ray
  - E(2+), E(4+), ..
  - Isomeric states
- Neutron emission
- New isotopes

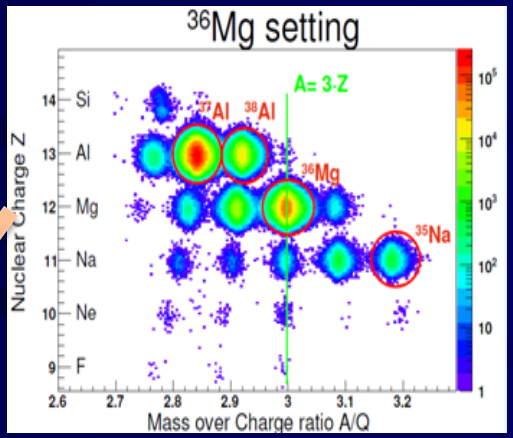
78Ni 7.5 days (SN) →Talk by Xu
81Cu 5.5 days (M.Niikura)

70Fe .. 5 days (G.Venzoni)

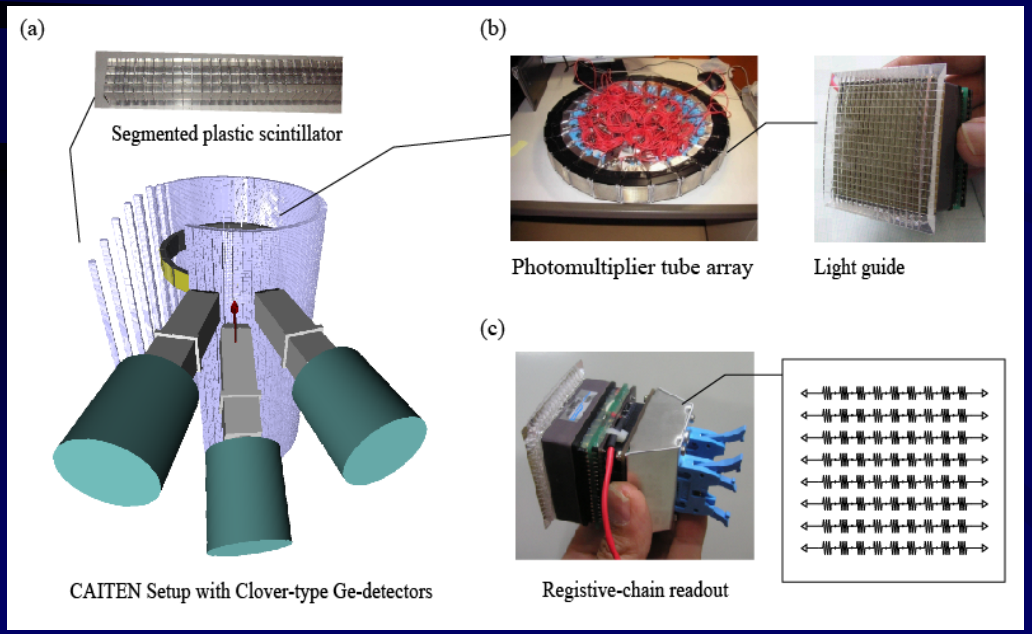
A lots of interesting results are coming from EUIRCA at RIBF!

Fast-timing beta-counting system: CAITEN





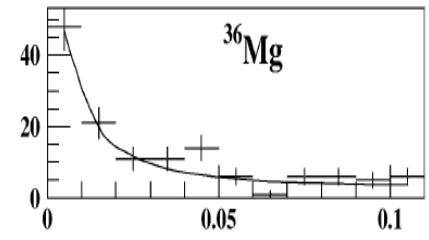
Beta-delayed gamma of ^{37}Al



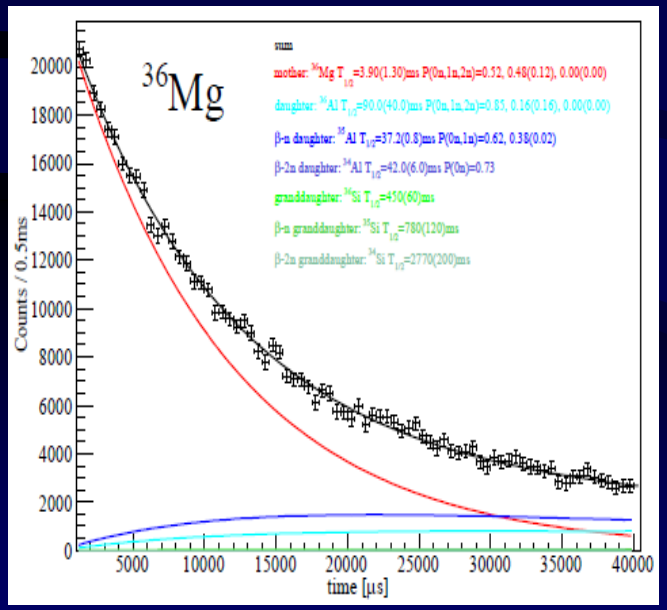
K.Steiger, Z.Li

CAITEN : $T_{1/2}$ measurement

S.Grevy, et al. (2004)

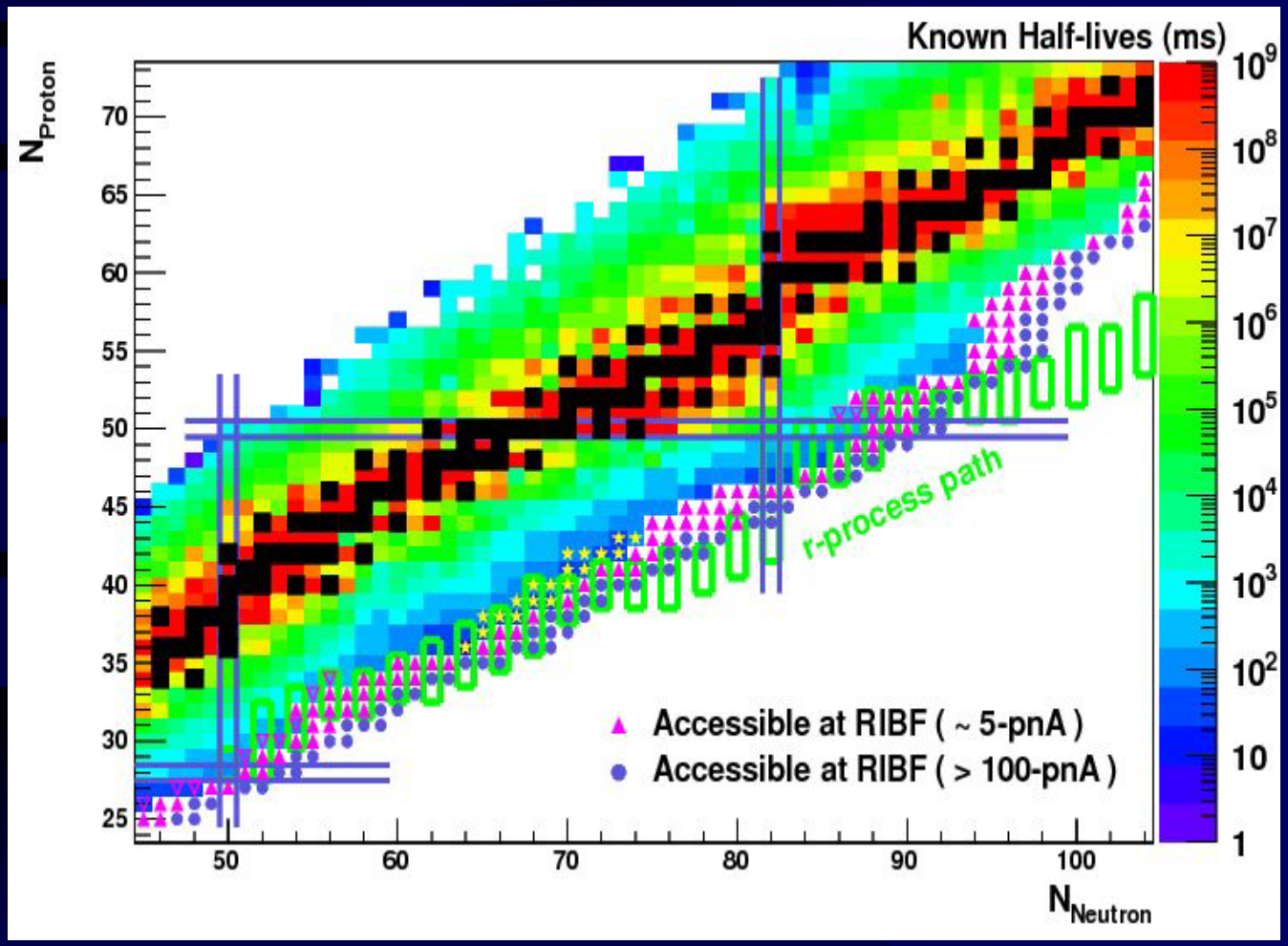


High statistic



High precision $T_{1/2}$ measurement
(implantation rate ~ 1 kcps)

In five years… (U-beam int. ≥ 100 pnA!?)



Several hundreds of new beta-decay half-lives in five years.
→ Significant contribution in nuclear structure and r-process nucleosynthesis.

Acknowledgement

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CAITEN Collaboration

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