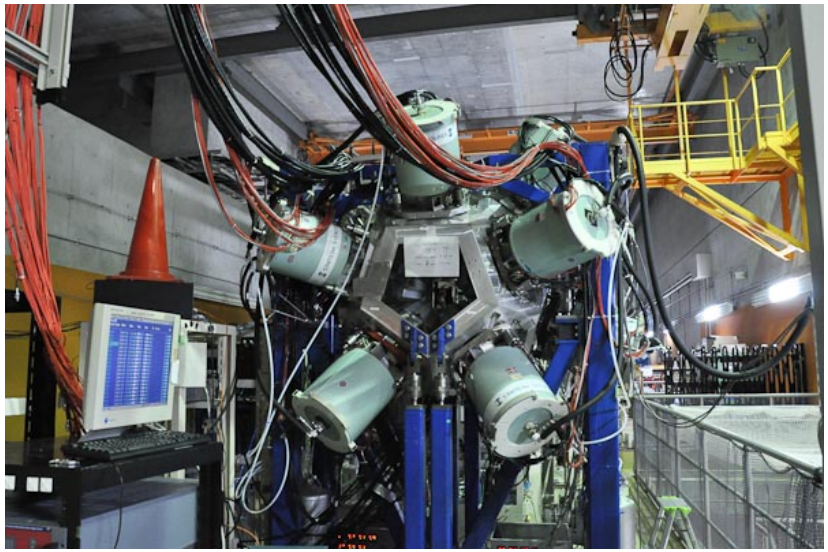
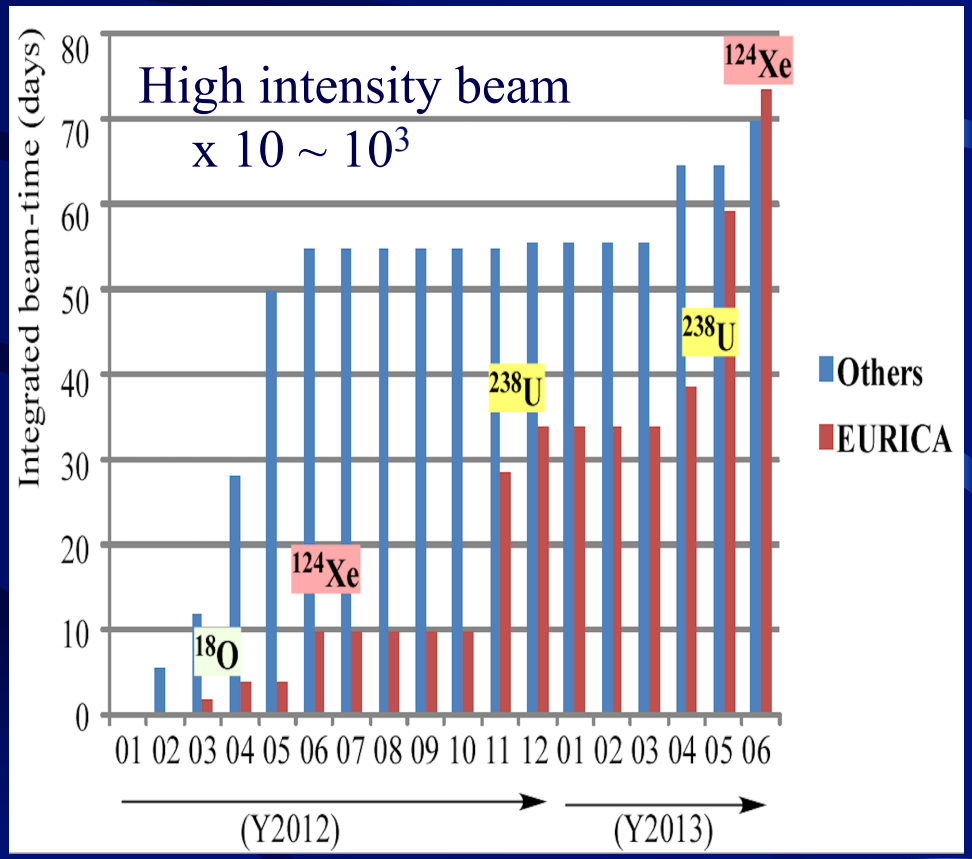
4th European Gamma and Ancillary detectors network: EGAN (June 25, 2014), GSI

Decay Properties of Exotic Nuclei with the EURICA

Shunji NISHIMURA (RIKEN, Japan)
for the EURICA collaboration



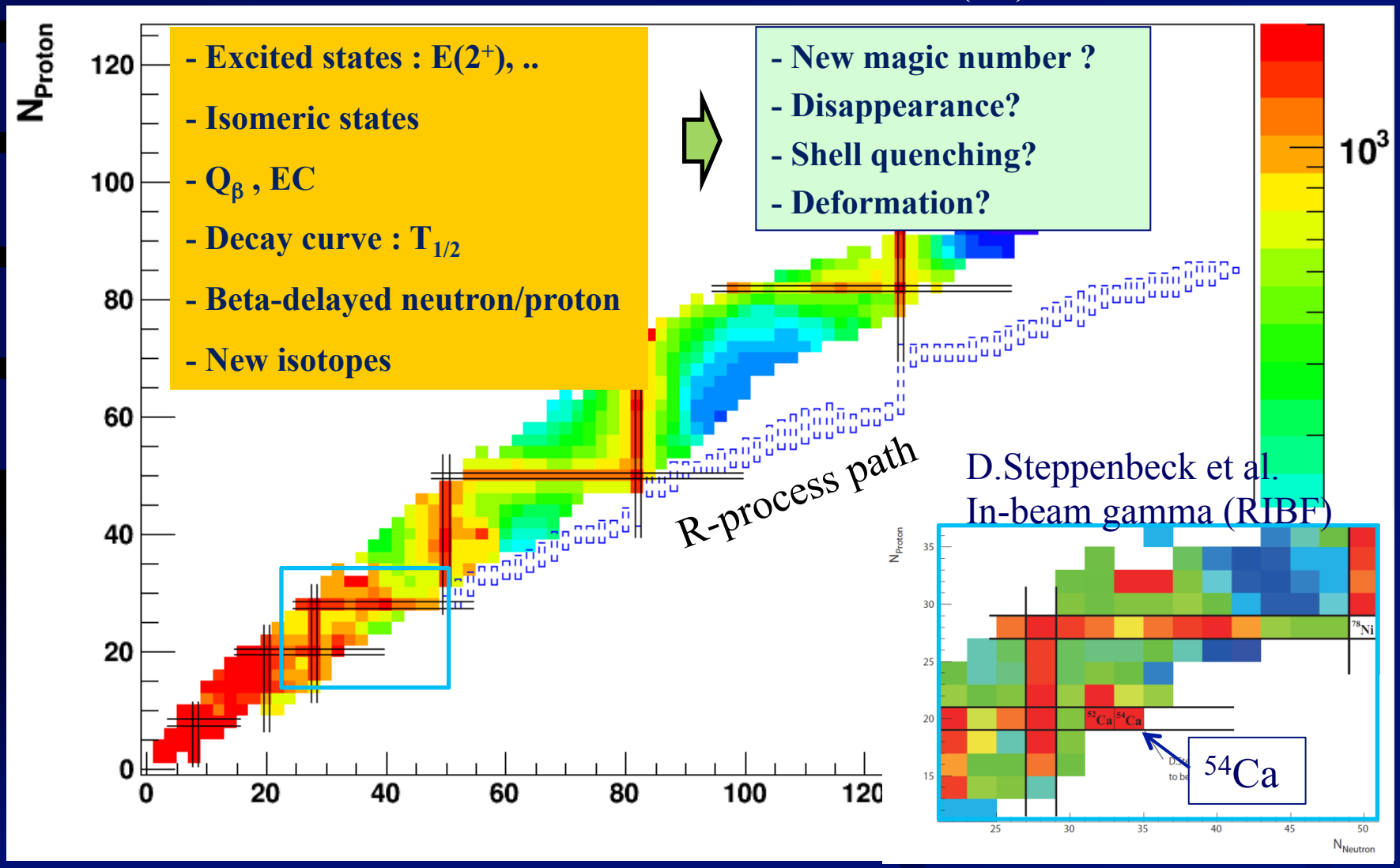


70 days of beam time for EURICA

10 days .. SEASTAR + EURICA(parasitic) in 2014

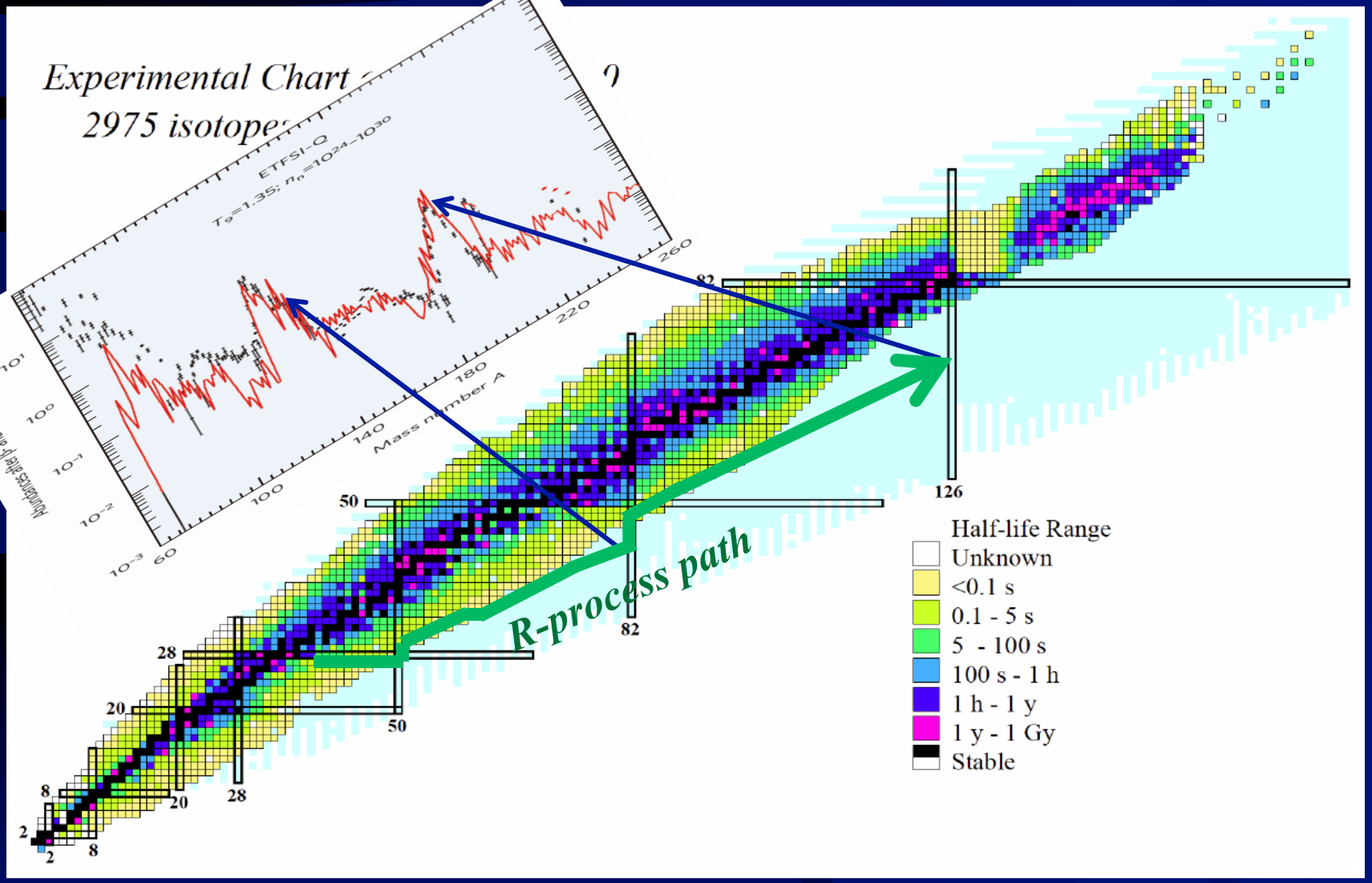
Survey of Nuclear Properties (Decay Spectroscopy)

First E(2+) for even-even nuclei



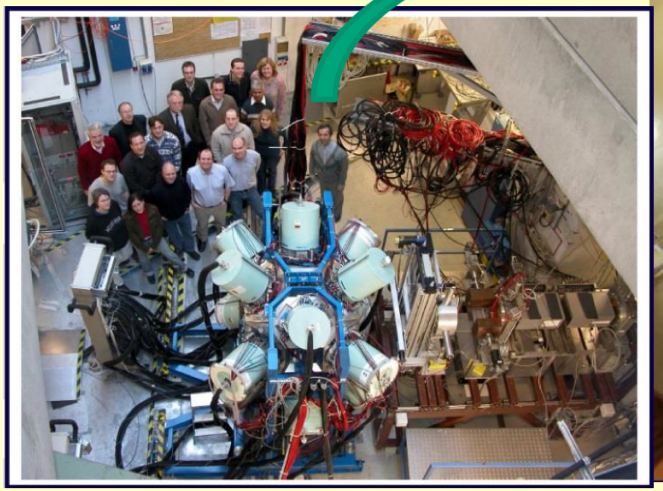
Very Neutron-Rich Nuclei & Proton-rich Nuclei

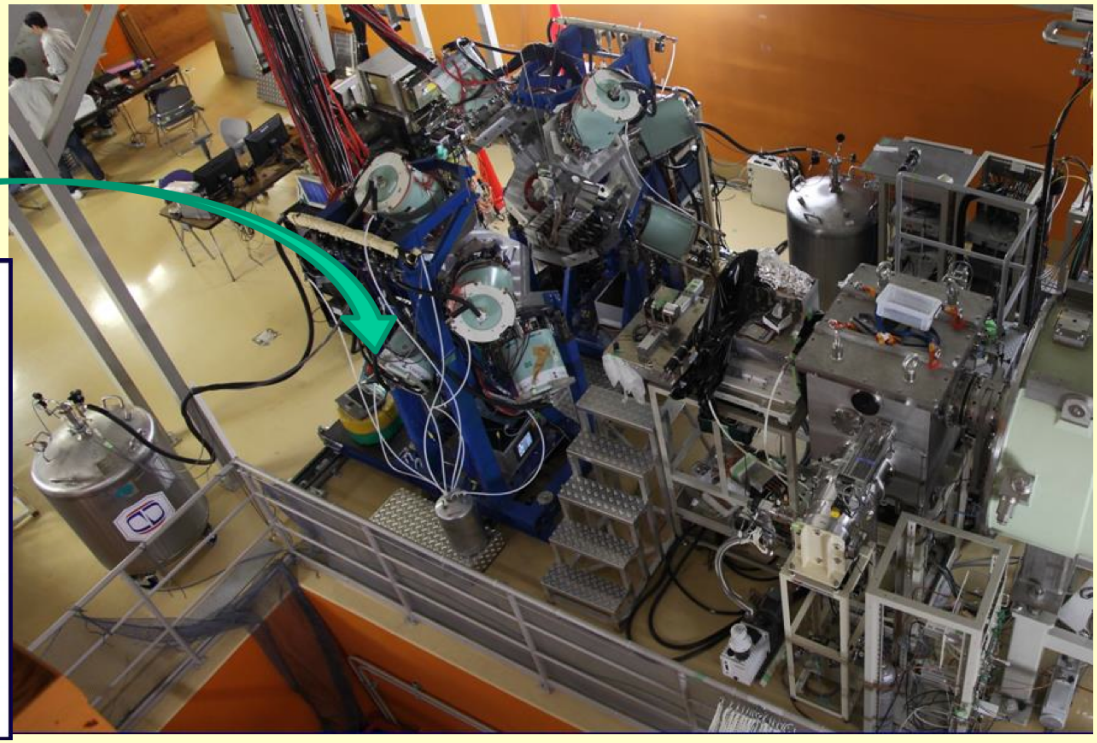
(Far from the stability..)



EURICA (EUroball-RIKEN Cluster Array)

12 EUROBALL Cluster detectors, i.e. 84 Ge crystals





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

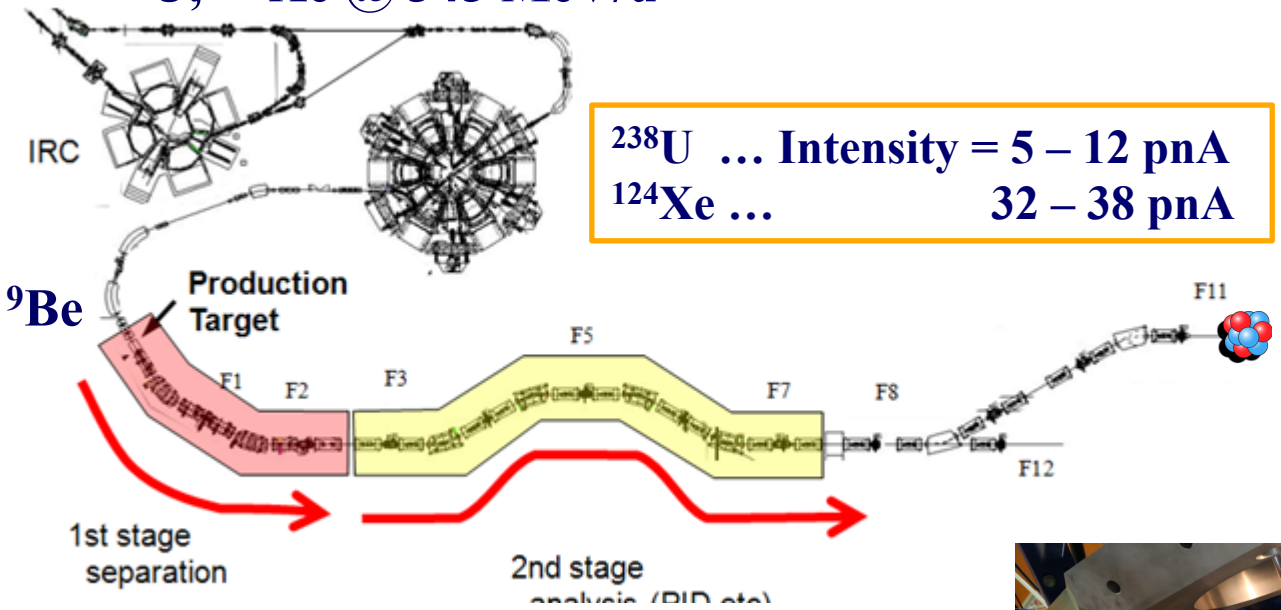
RIKEN RIBF (Japan)

理化学研究所 RIKEN

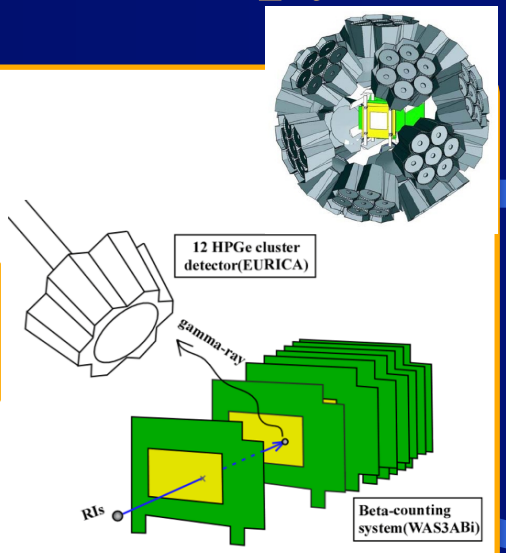
Installation completed in 2012 Feb.

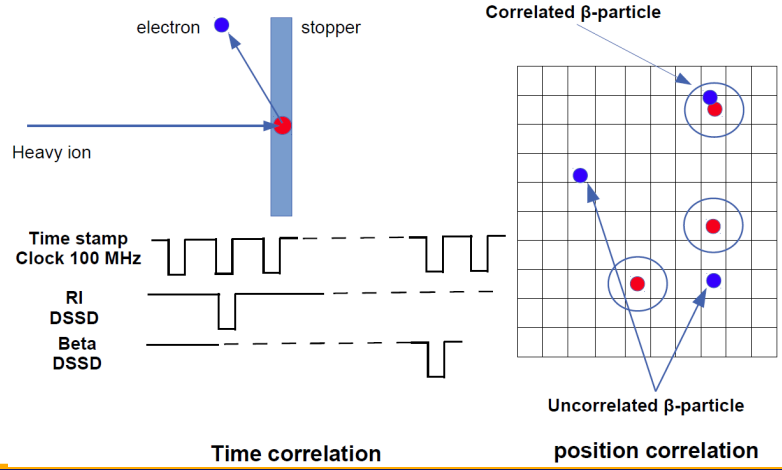
RI Production and Decay Spectroscopy

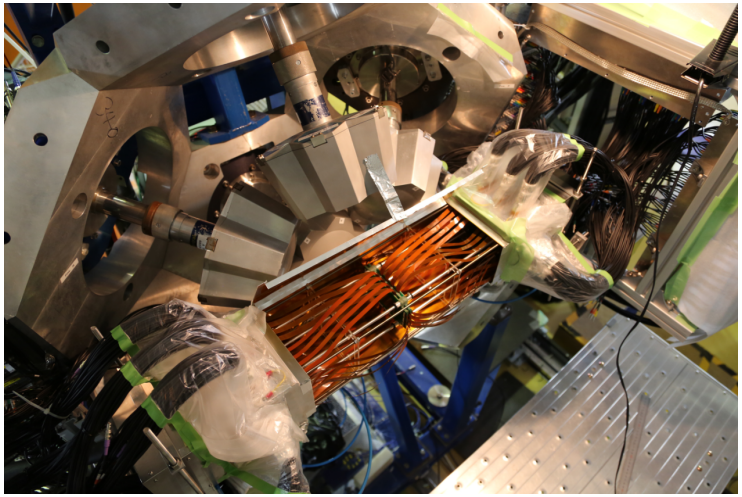
^{238}U, ^{124}Xe @ 345 MeV/u



^{238}U … Intensity = 5 – 12 pnA
^{124}Xe … 32 – 38 pnA





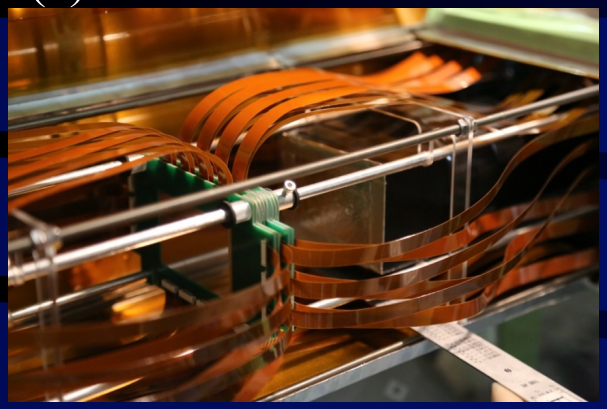


Beta-counting system: WAS3ABi in EUIRCA

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

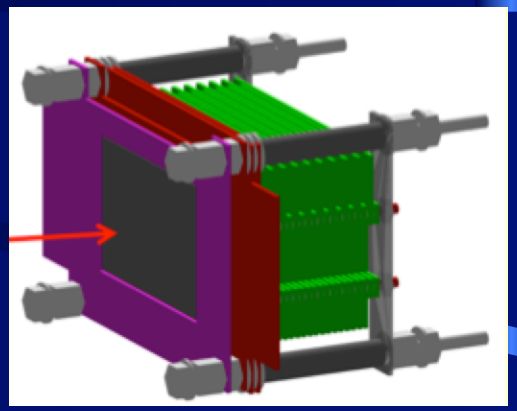
RIKEN/TU München/IBS

(a)

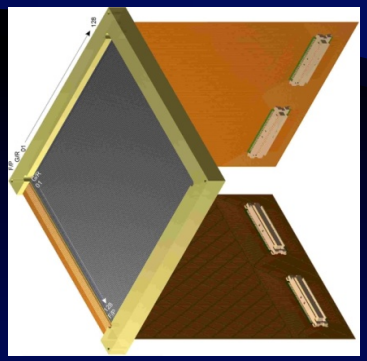


(b)

(c)



(d)



Heavy-ion … ~ 1GeV ~ 10 GeV (optional)

Beta-ray … 20 keV ~ 3 MeV

High segmentation … 60 x 40mm2, 1mm strips
Up to 16,000 pixels

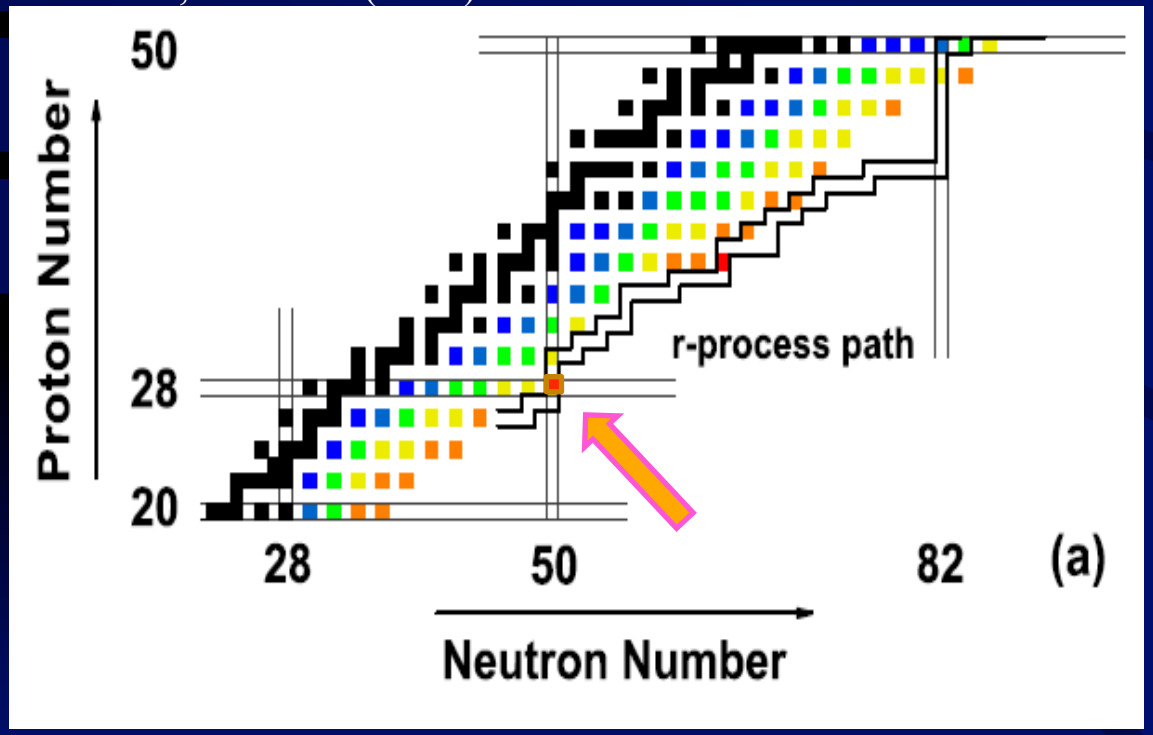
Qbeta …. Plastic scintillator or SSSD x 10

Fast timing … Plastic scintillators

Radiation …. Cooled by cold N2 air flow (10 ℃)

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

Z.M.Niu, PLB 723 (2013)



[History of ^{78}Ni]

-1997

Identified as new isotope (3 events)

M.Bernas et al., PLB415 (1997)

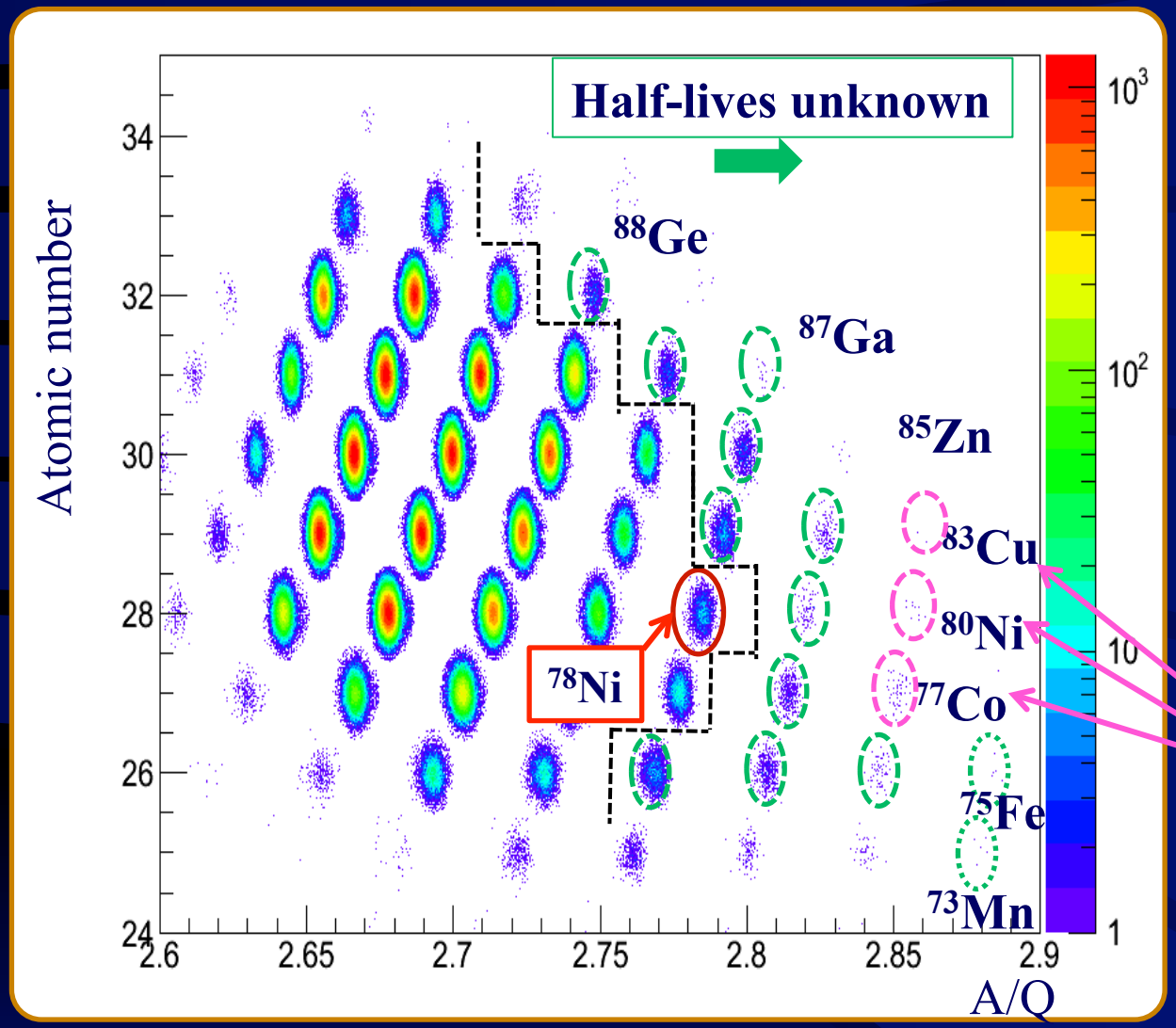
- 2005

Beta-decay half-life (11 events)

$T_{1/2} \sim 110^{+100}_{-60}$ ms

T.Hosmer et al., PRL94 (2005)

RIBF: Decay Experiment around ^{78}Ni region



Spokesperson : SN / Niikura

Implantation rate
= 20 ~ 50 pps

New isotopes
(7 Candidates)

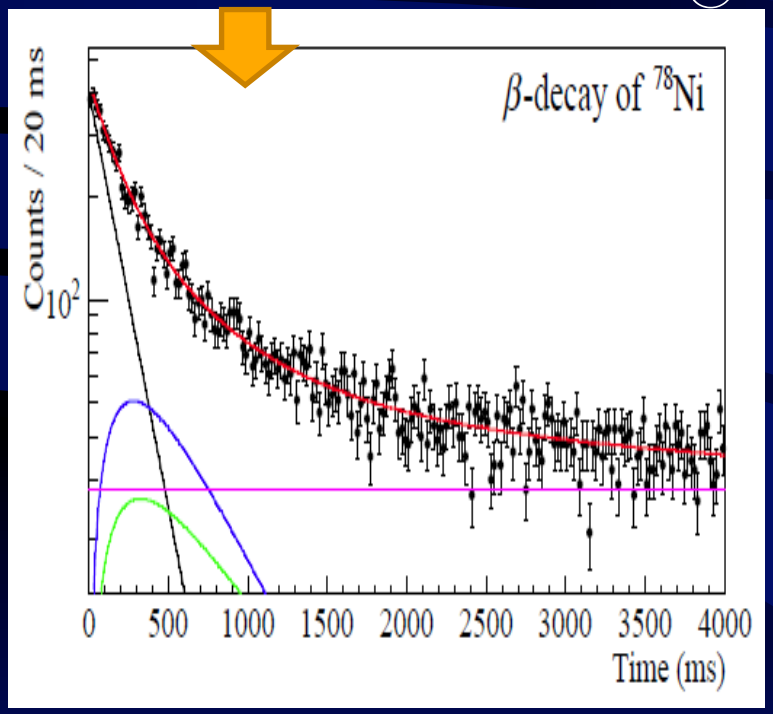
- Isomer search
- Beta-delayed gamma in progress…

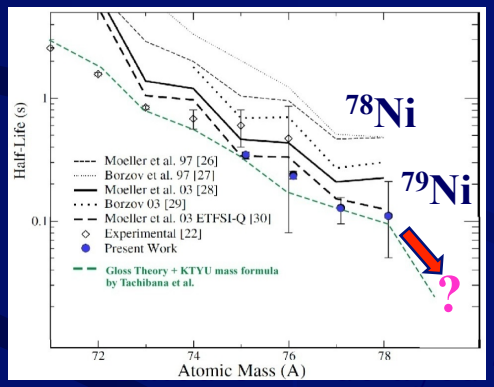
~ 12 k of ^{78}Ni produced at the RIBF.
Low production yield of ^{79}Ni (^{78}Ni + neutron)

^{78}Ni beta-decay half-life

Hosmer (MSU)
PRL (2006)

Z.Xu PhD@U.Tokyo

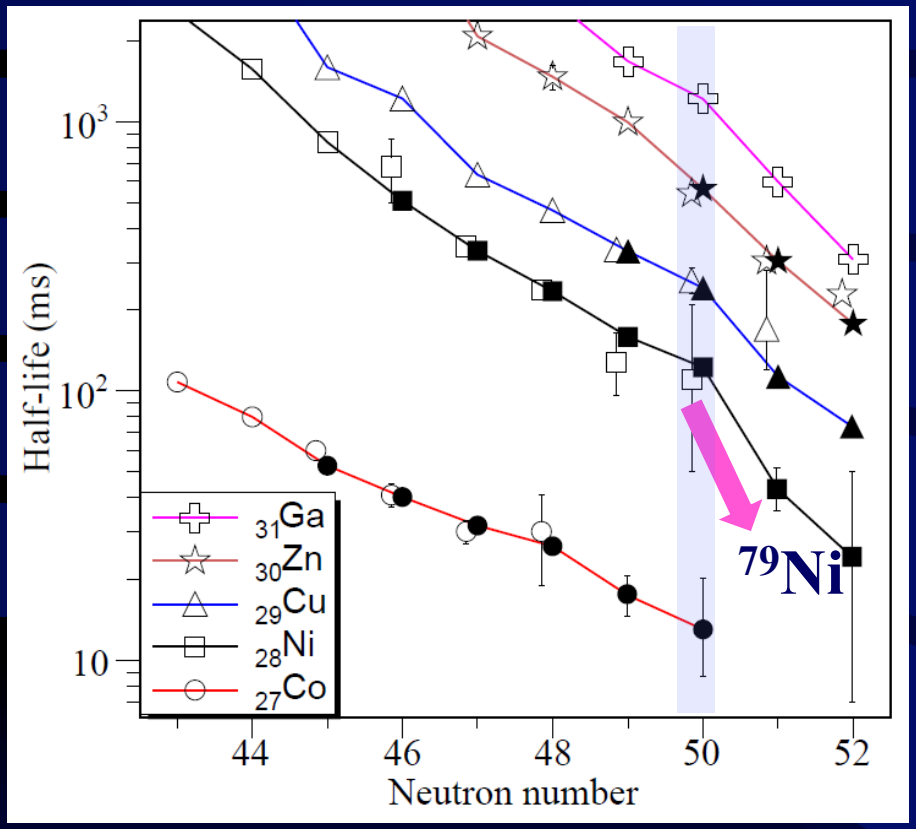


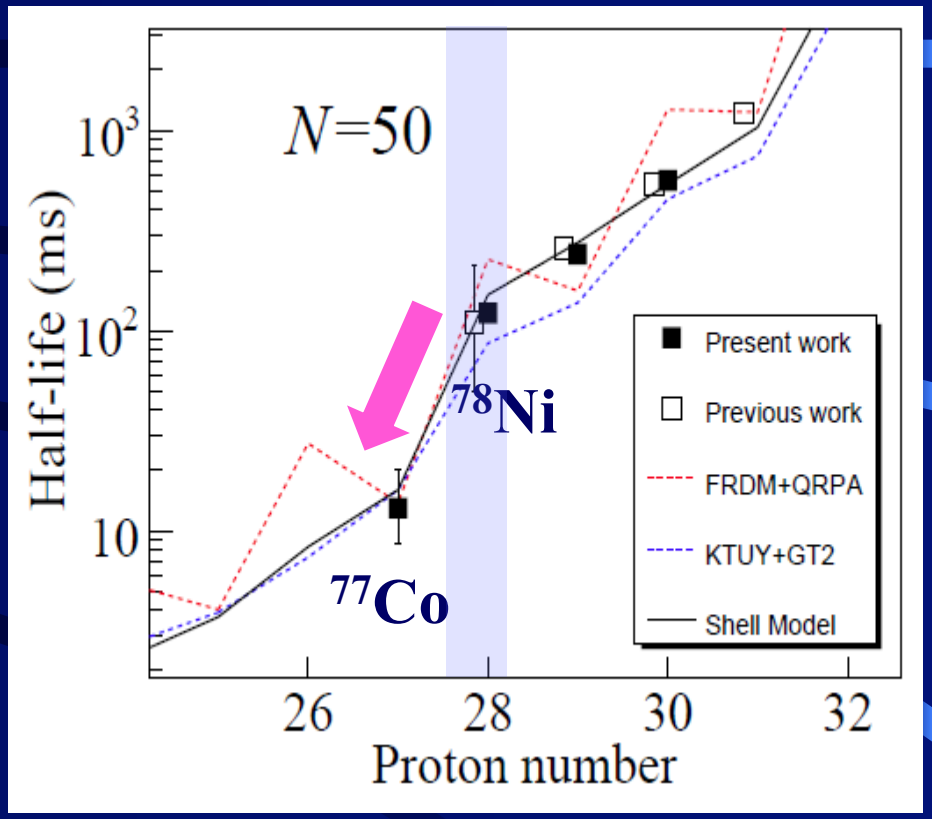


Decay spectra obtained in WAS3ABi and with EURICA.
What about N=51 (^{79}Ni)? Z=27 (^{77}Co)?

Beta-decay half-lives beyond ^{78}Ni

Z.Y.Xu, submitted.



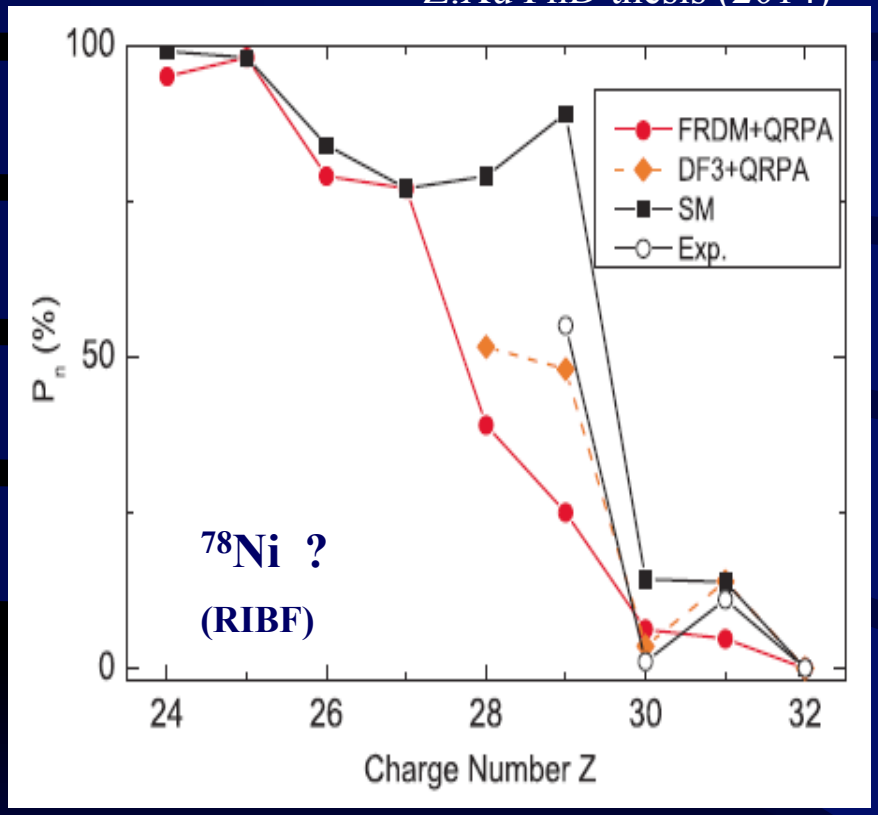


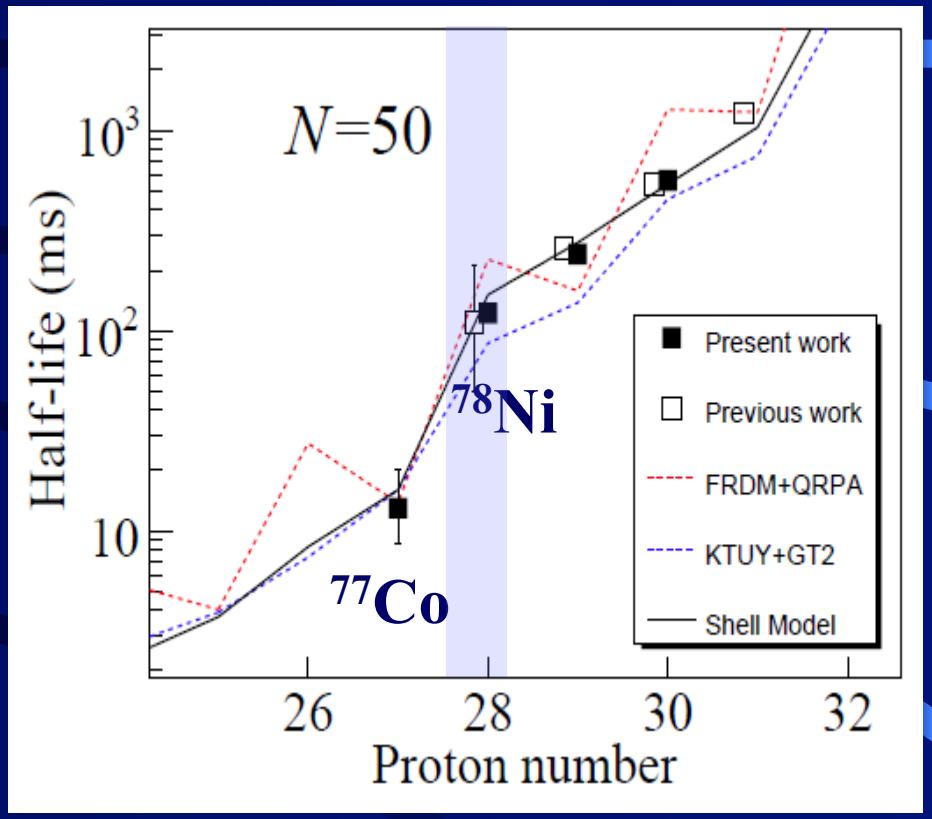
Shorter T1/2 beyond ^{78}Ni → Pronounced in Z = 28, N=50
→ ^{78}Ni is double magic nuclei !?

Half-lives and Pn on N = 50

(Experiment ←→ Theory)

Z.Xu PhD thesis (2014)



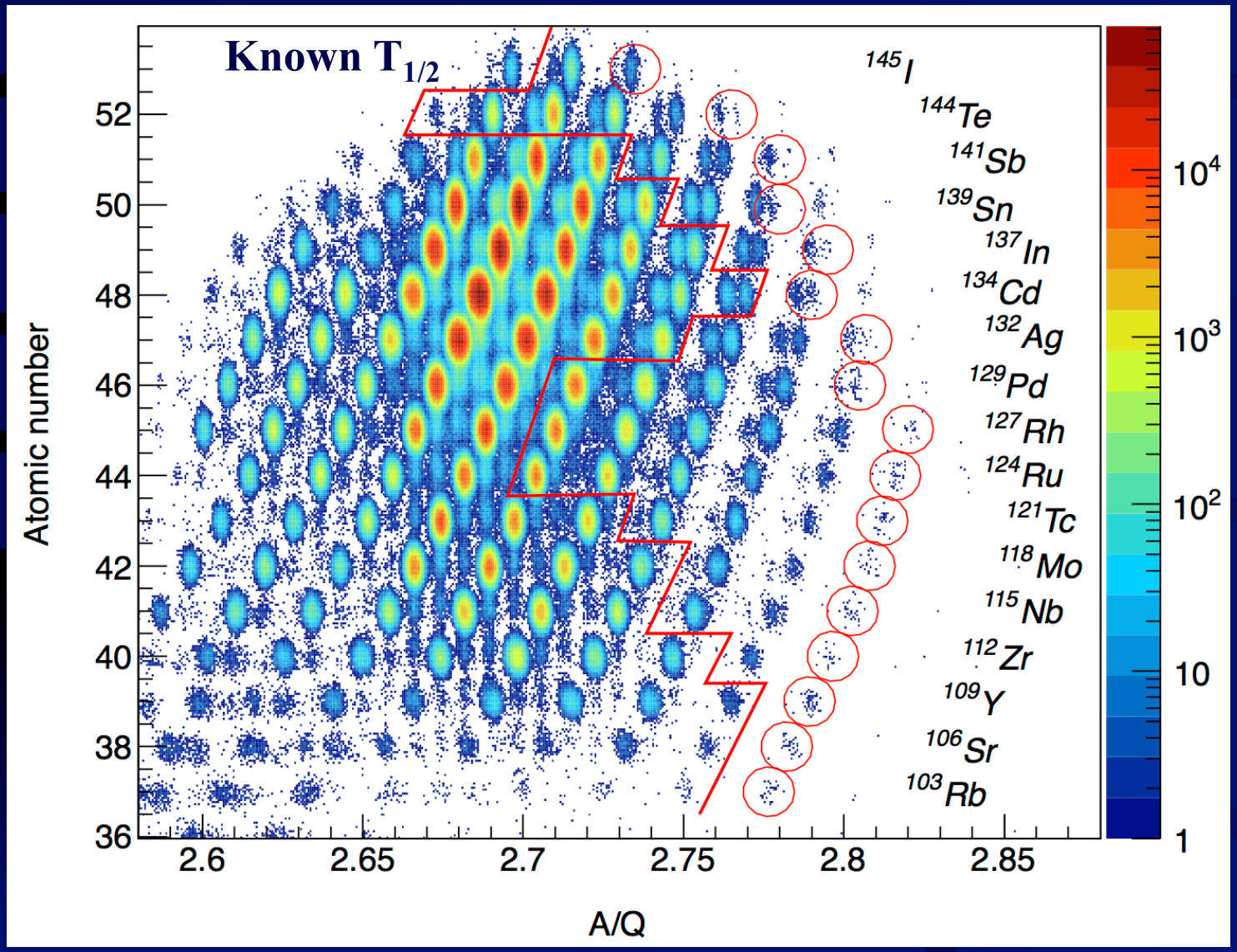


Decay properties around double magic ^{132}Sn (Z=50, N=82)

Decay Spectroscopy around A = 100 ~ 145

U-beam: 8 – 10 pnA
~ Two weeks

Two EURICA data sets: G.Simpson/A.Jungclaus & H.Watanabe/G.Lorusso

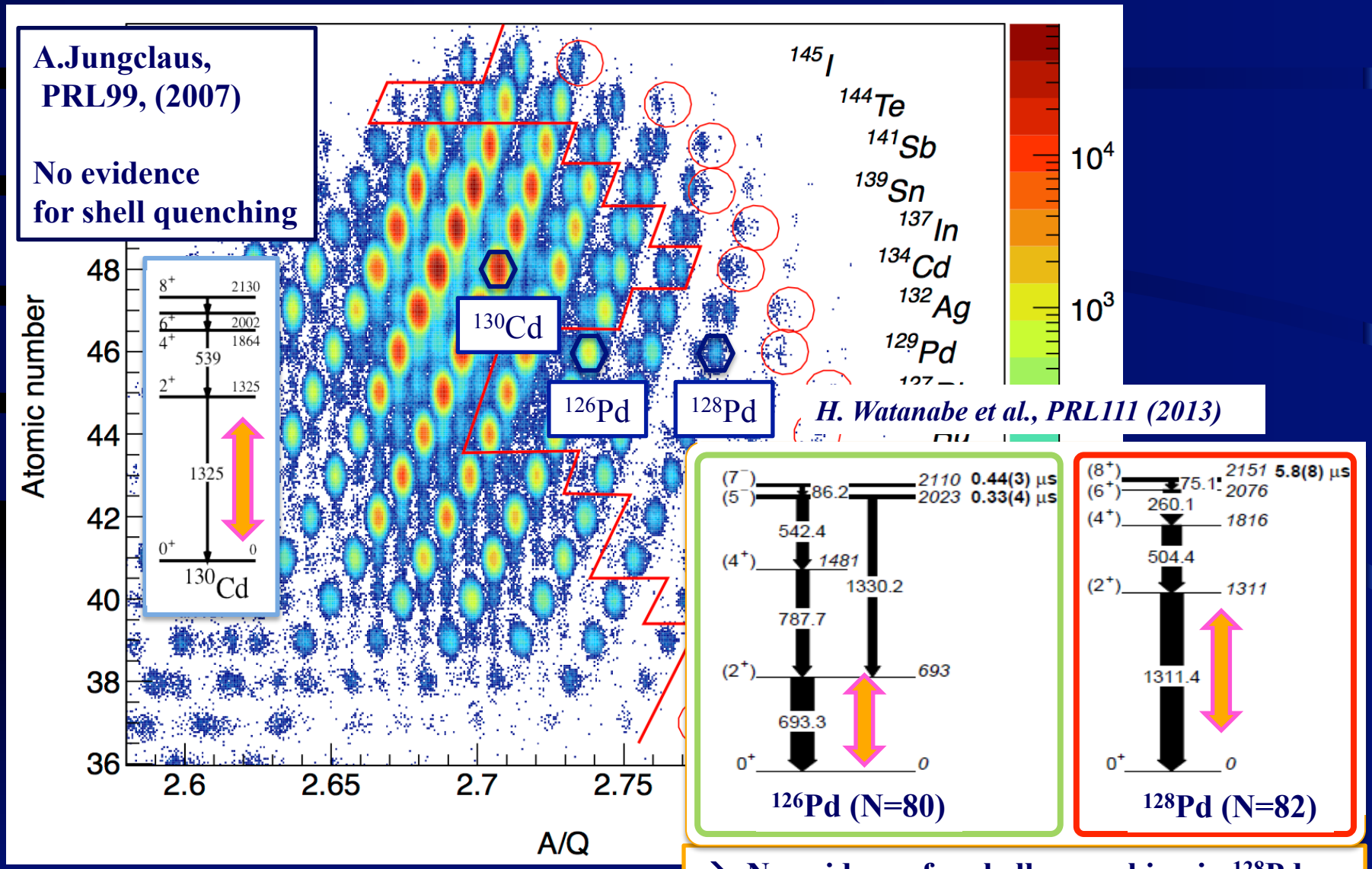


New Isotopes

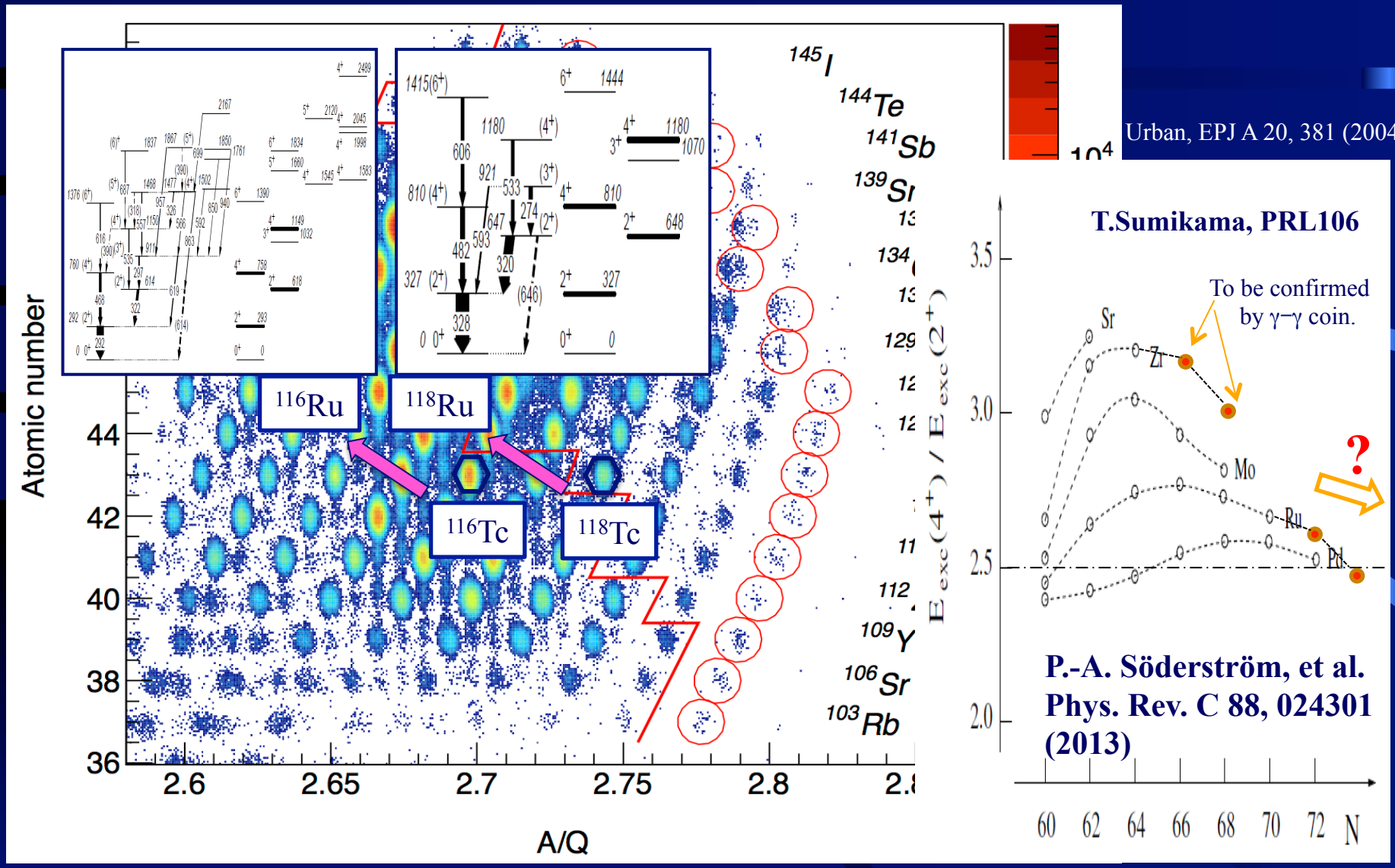
^{144}Te
^{140}Sb
$^{139,140}Sn$
$^{136,137}In$
$^{134,135}Cd$
$^{131,132}Ag$
$^{129,130}Pd$
^{127}Rh
$^{120,121}Tc$
^{118}Mo

and more..

Decay Spectroscopy around A = 100 ~ 145

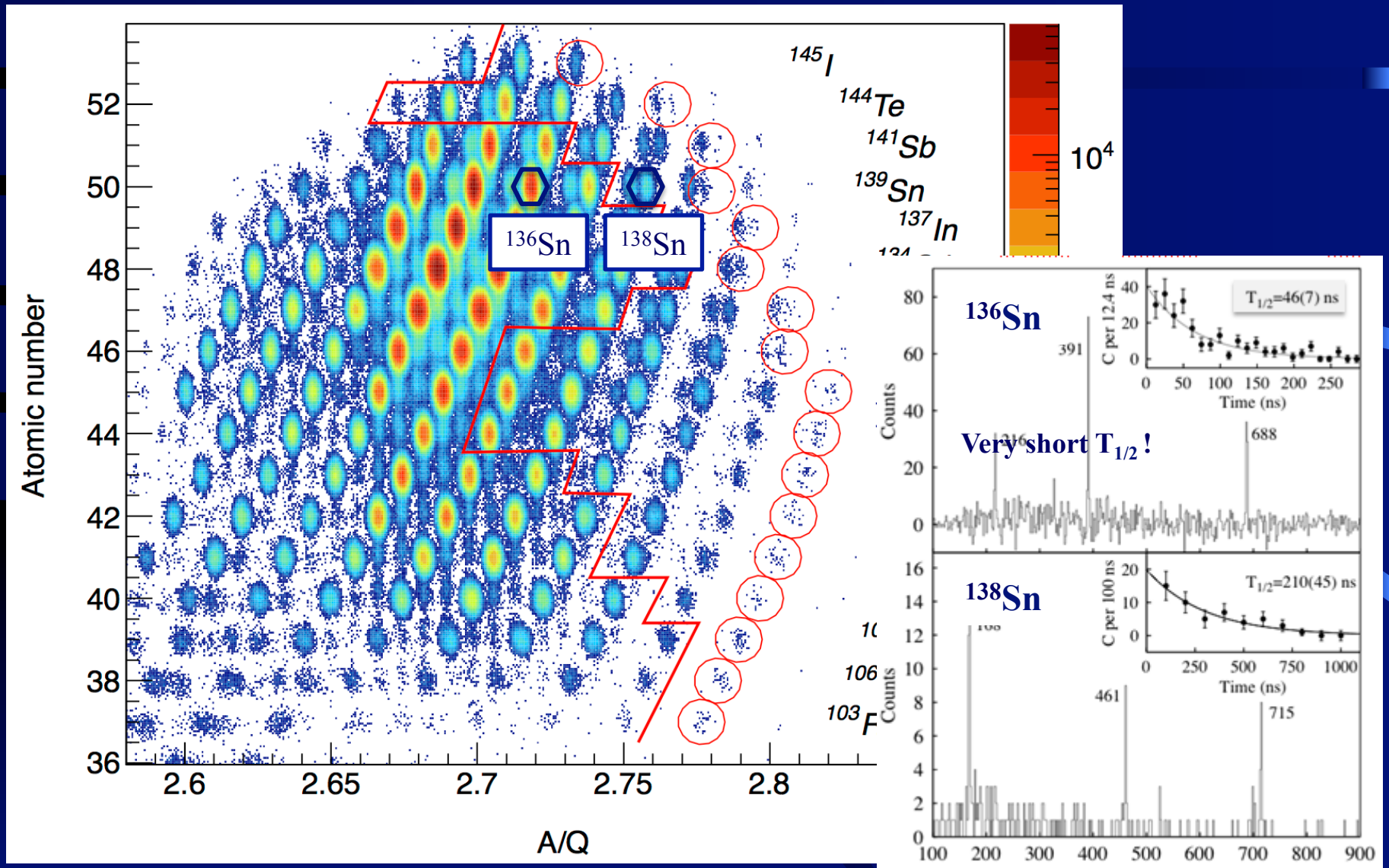


Decay Spectroscopy around A = 100 ~ 145

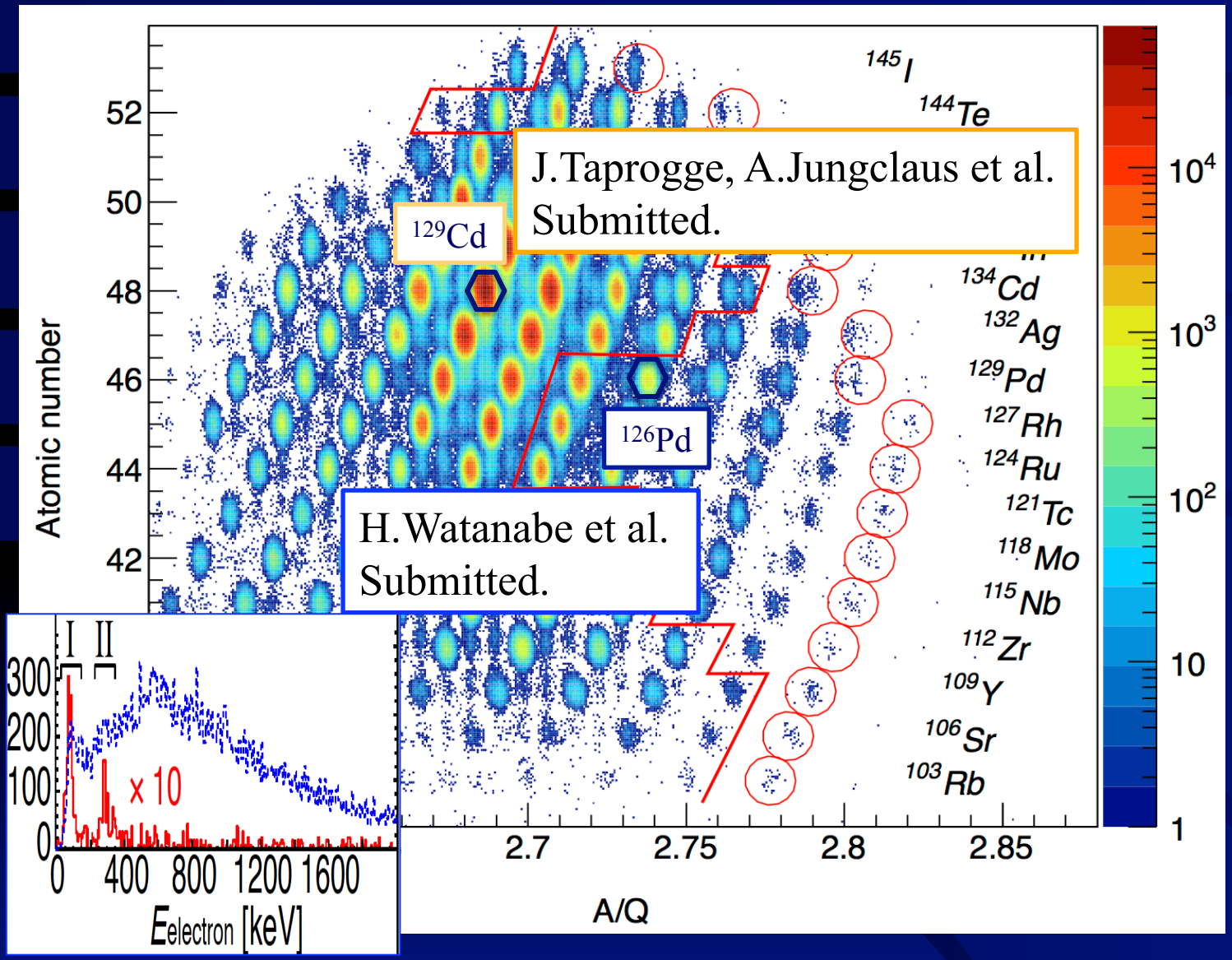


Decay Spectroscopy around A = 100 ~ 145

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

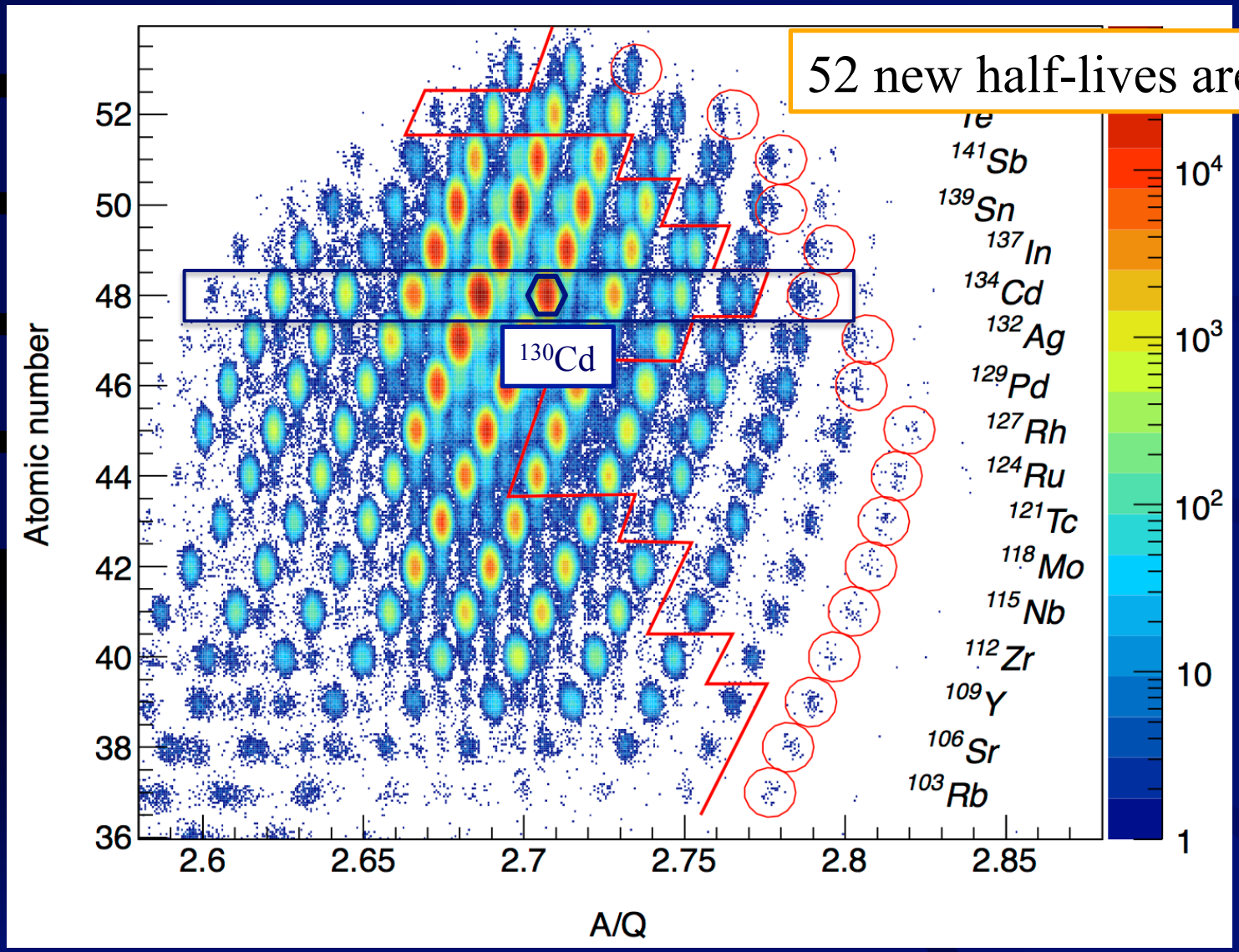


Identification of milisecond Isomeric States via detection of conversion electrons

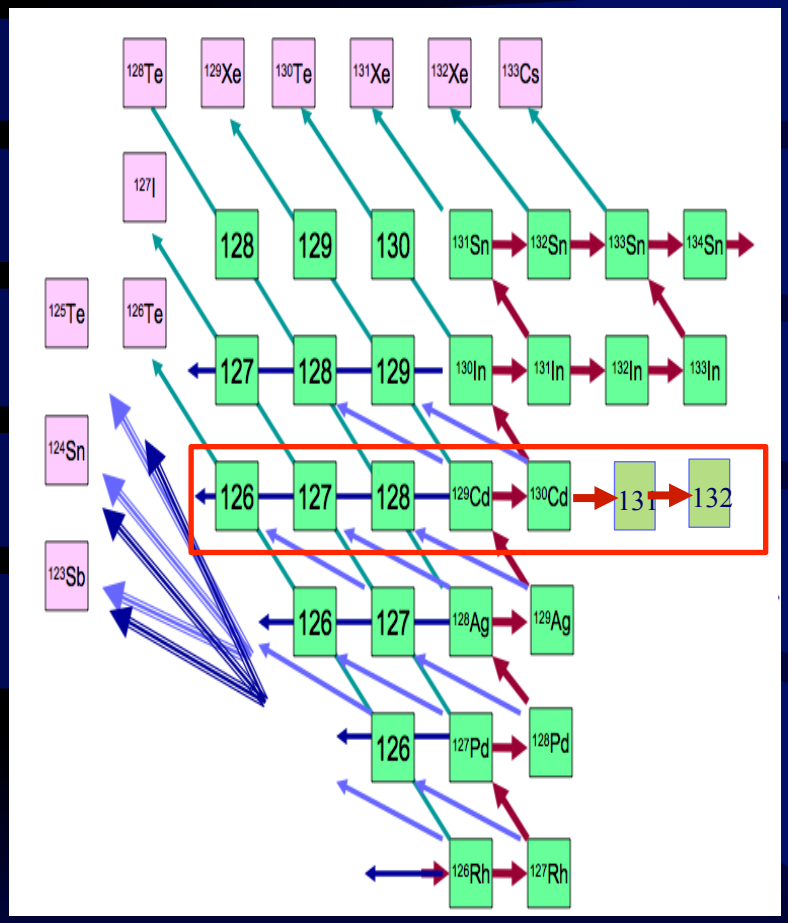


β-decay half-lives on r-Process path

G.Lorusso @ RIKEN



Beta-decay half-lives of Cd isotopes (RIBF)



G.Lorusso@RIKEN

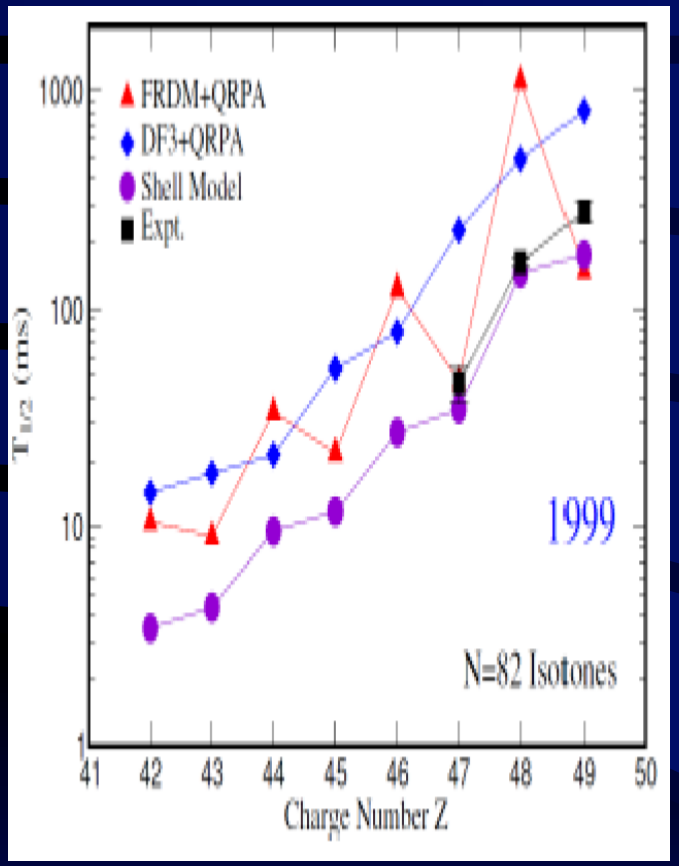
Significant impact to SM calc. & r-process simulation !

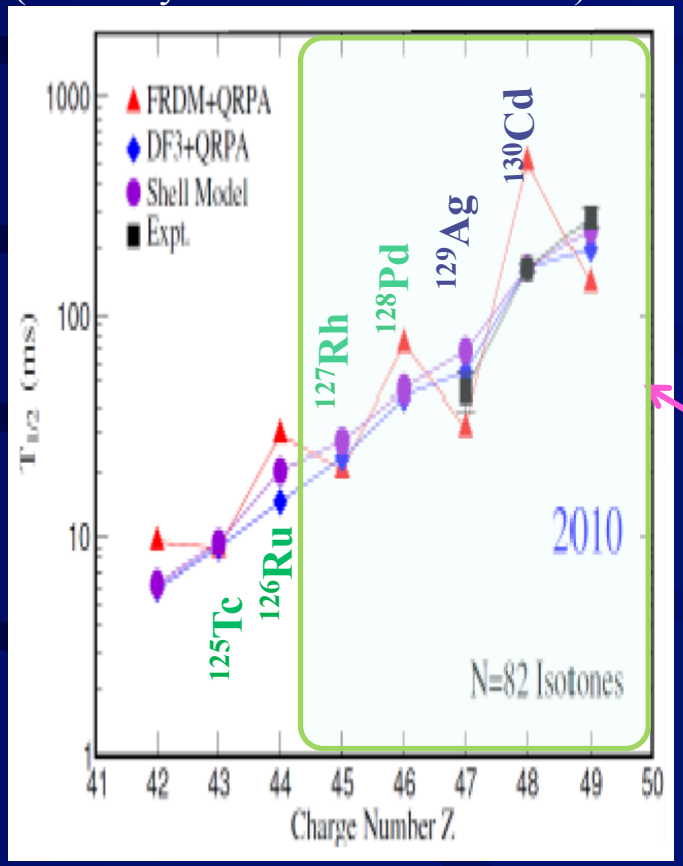
Beta-delayed gamma of ^{131,132}Cd → ^{131}In.

^{130}Cd isomer: Consistent
RISING – EURICA
(GSI) (RIBF)

Beta-decay Half-lives N = 82
→ Feedback to the Theory

K.Langanke Phys. Scr. T152 (2013) 014011
(Courtesy of G. Martines-Pinedo)



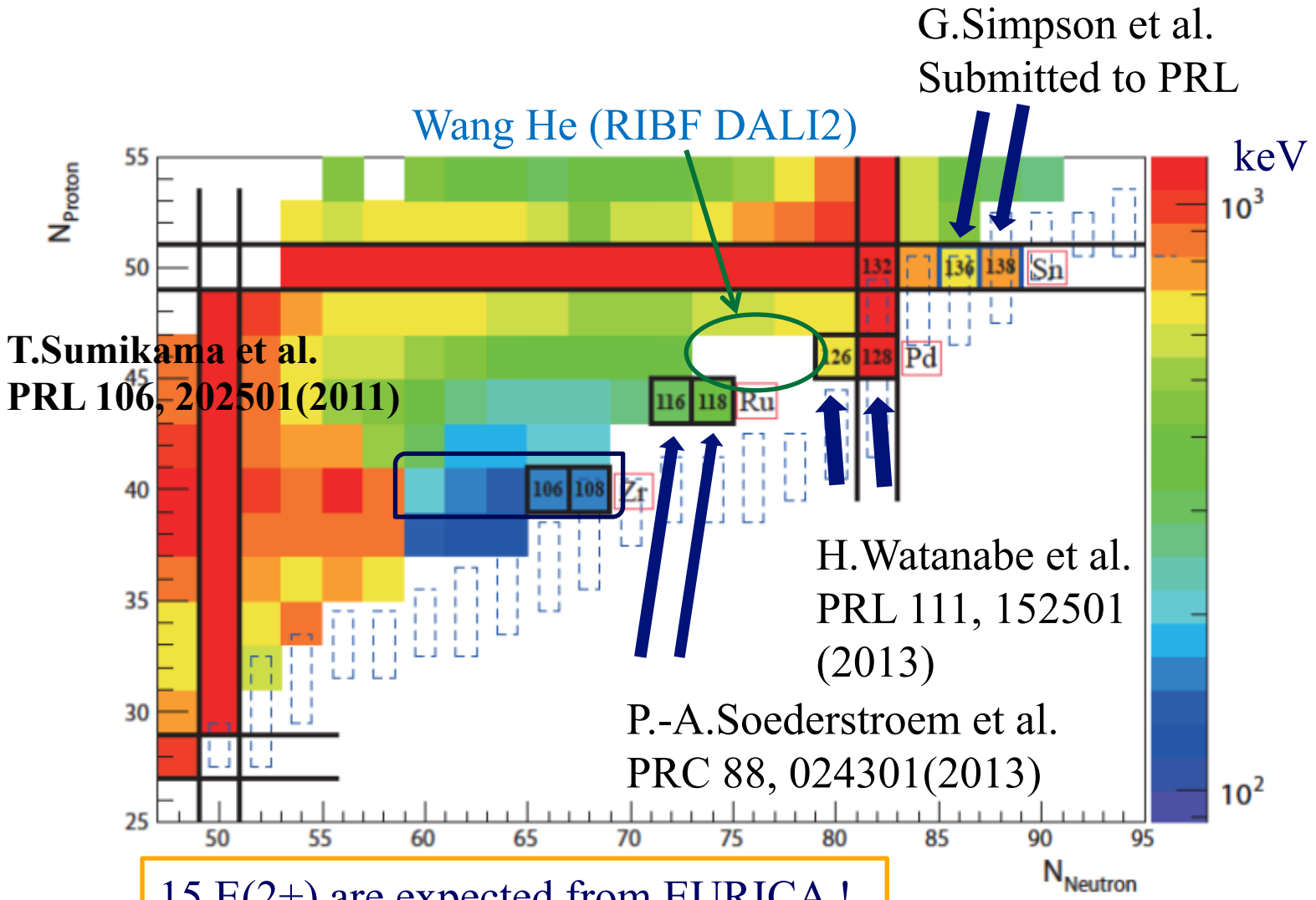


RIBF
EURICA

So call r-process waiting point nuclei (N=82)
- r-process path
- residual r-matter flow in freeze-out

$T_{1/2}$ of Cd isotopes (EURICA)

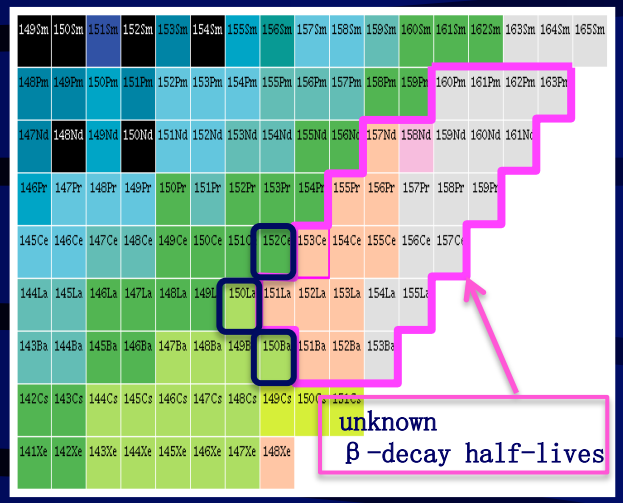
First Excited State: E(2+)

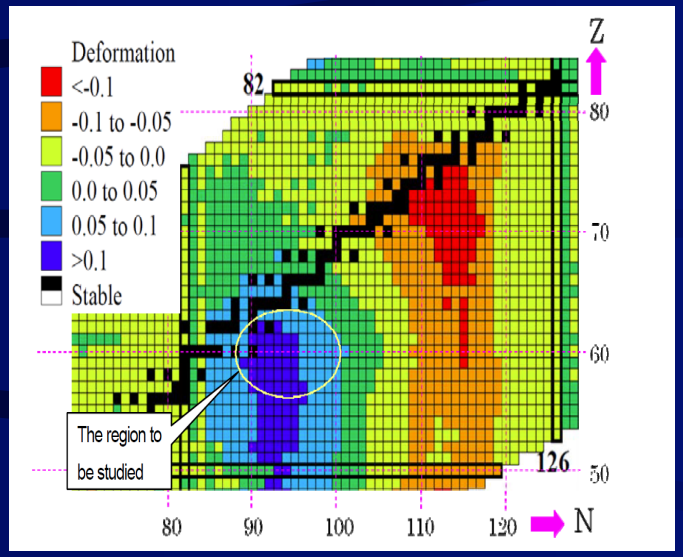


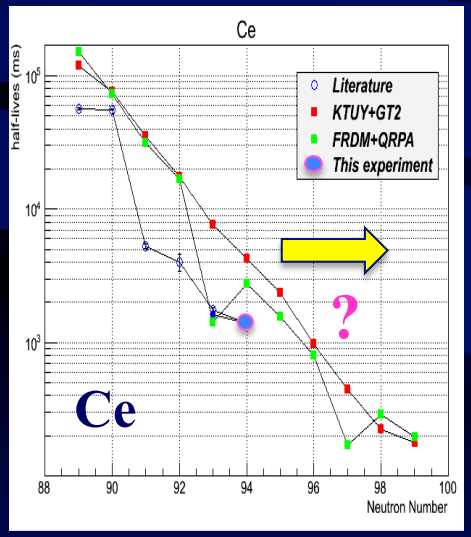
15 E(2+) are expected from EURICA !
And more …

Rare-earth peak (A ~ 160)

Spokesperson: E.Ideguchi/G.Simpson







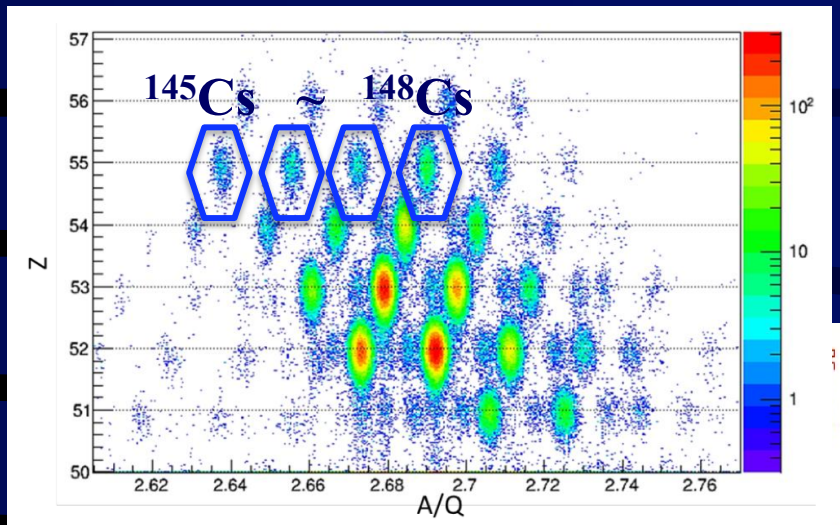
- 27 new beta-decay half-lives & Pn
  (W.Jin @ RIKEN/Peking)

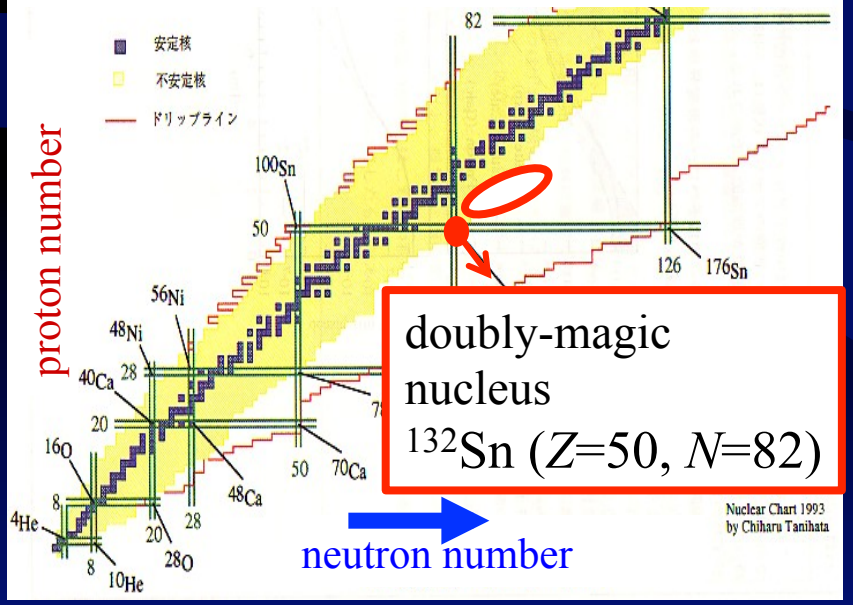
- Beta-gamma, isomer search
  (E.Ideguchi .. RCNP)
  (R.Yokoyama .. CNS)
  (Z.Patel … Surrey)

- Study of r-process nucleosynthesis at freeze-out time.
- Deformation, K-Isomers

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

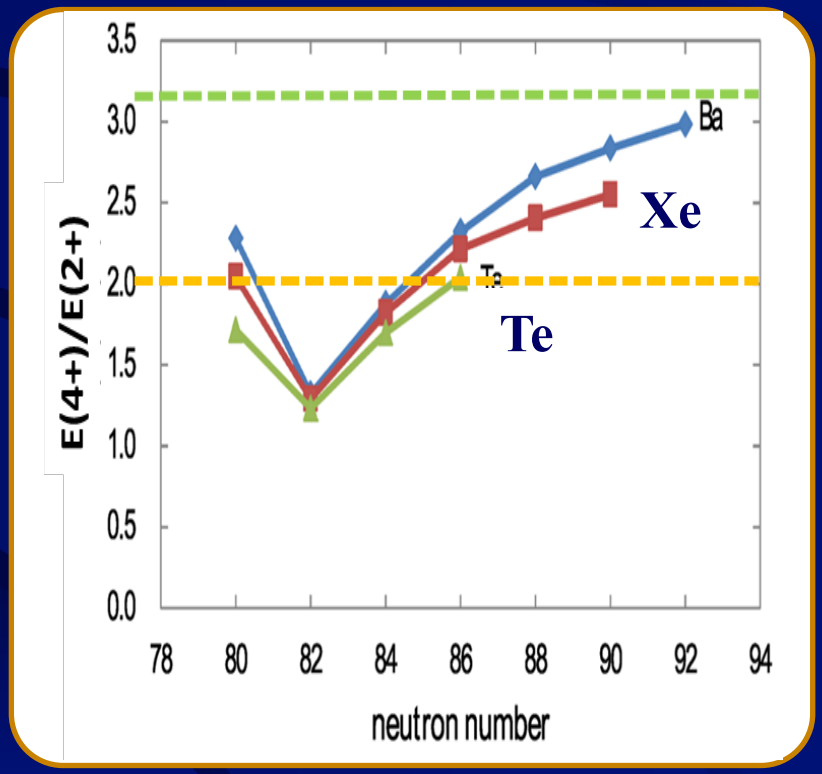
A. Odahara (Osaka),
R. Lozeva (IPH/DRS,Strasbourg)
C.B. Moon (Hoseo)





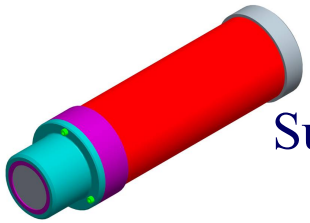
doubly-magic nucleus
^{132}Sn (Z=50, N=82)

New isomers in ^{145,146,147,148}Cs isotopes
… A.Yagi,Odahara
→ More isomers are coming..



Complementary $LaBr_3$ array for fast timing with EURICA

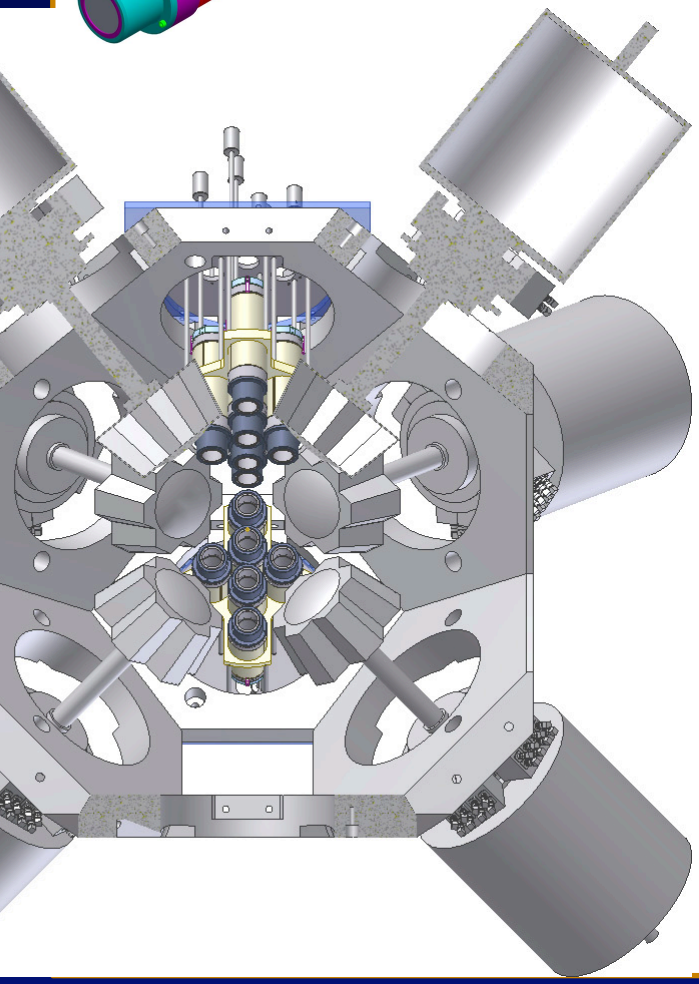
18 detectors
φ1.5” x 2”

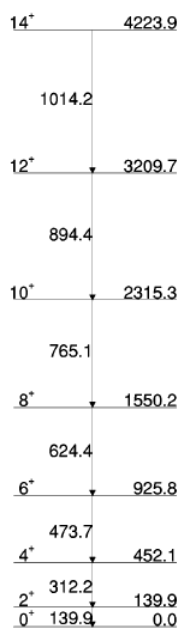


Surrey/Brighton

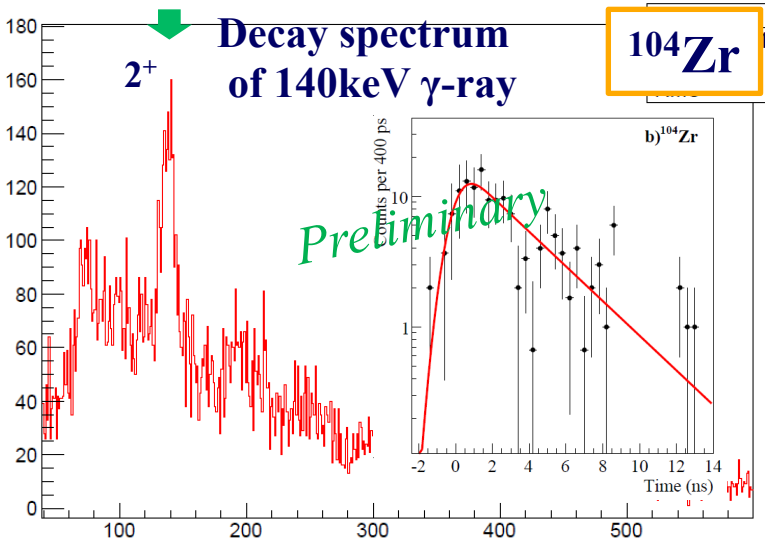
Spokesperson: T.Sumikama

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





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



F.Browne

Proton rich nuclei

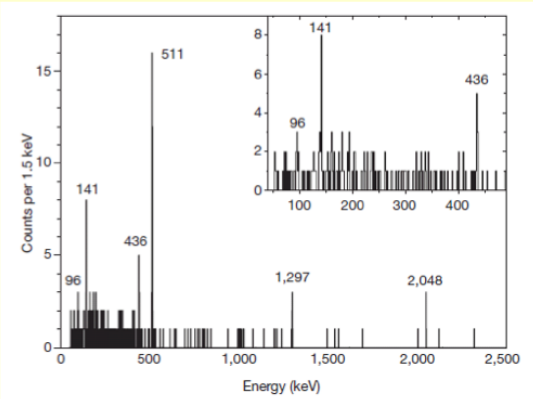
(EURICA)

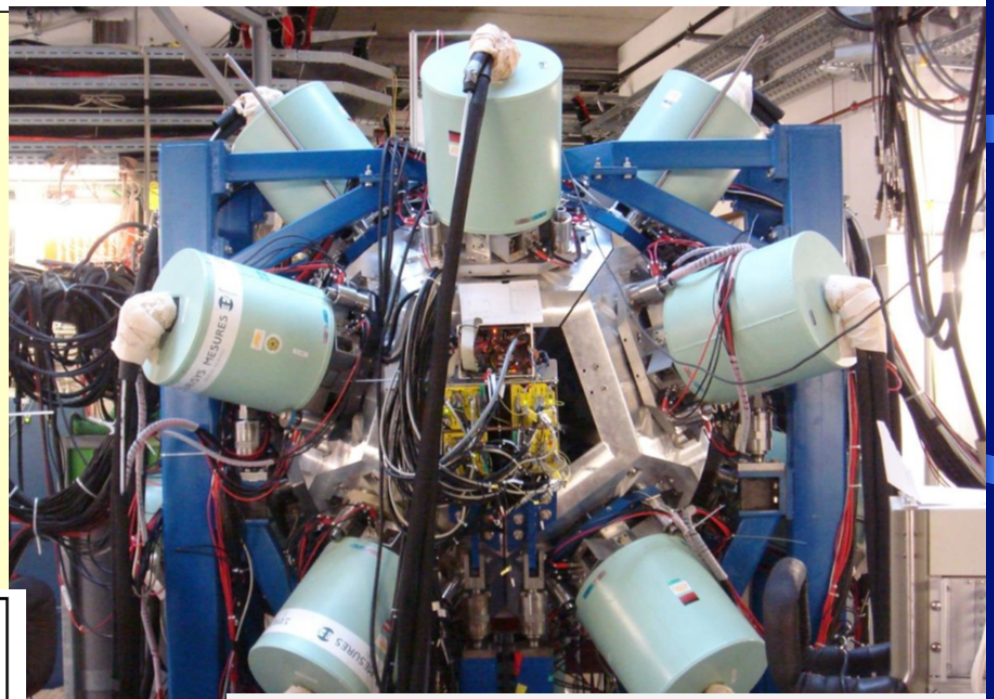
Rising at GSI

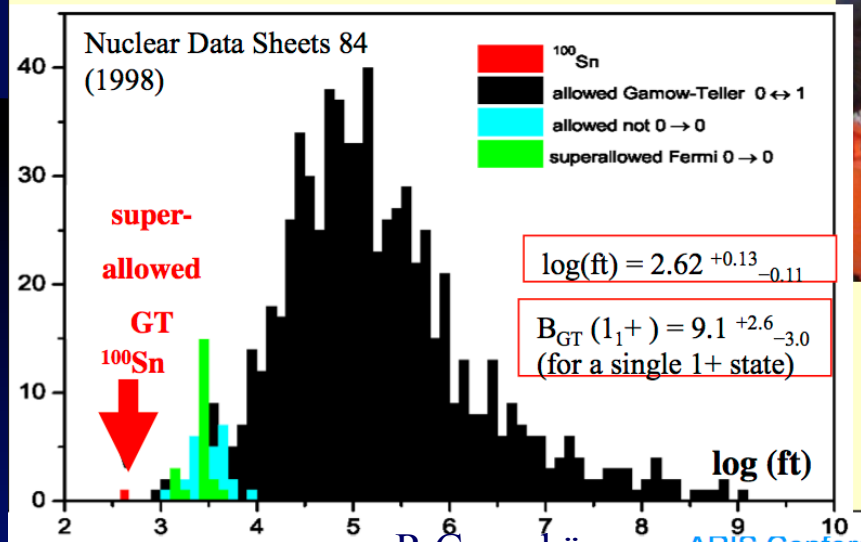
Lehrstuhl E12

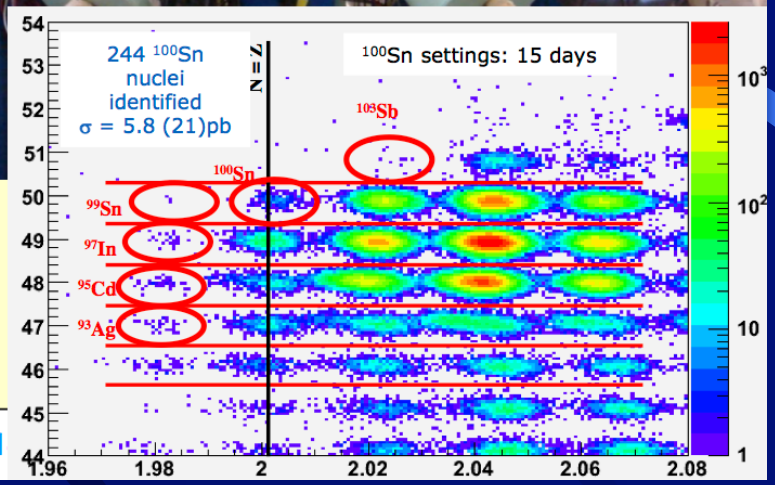
Superallowed Gamow–Teller decay of the doubly magic nucleus ^{100}Sn
Ch. Hinke et at., Nature 486, 341–345, June 2012

Decay γ spectrum of ^{100}Sn









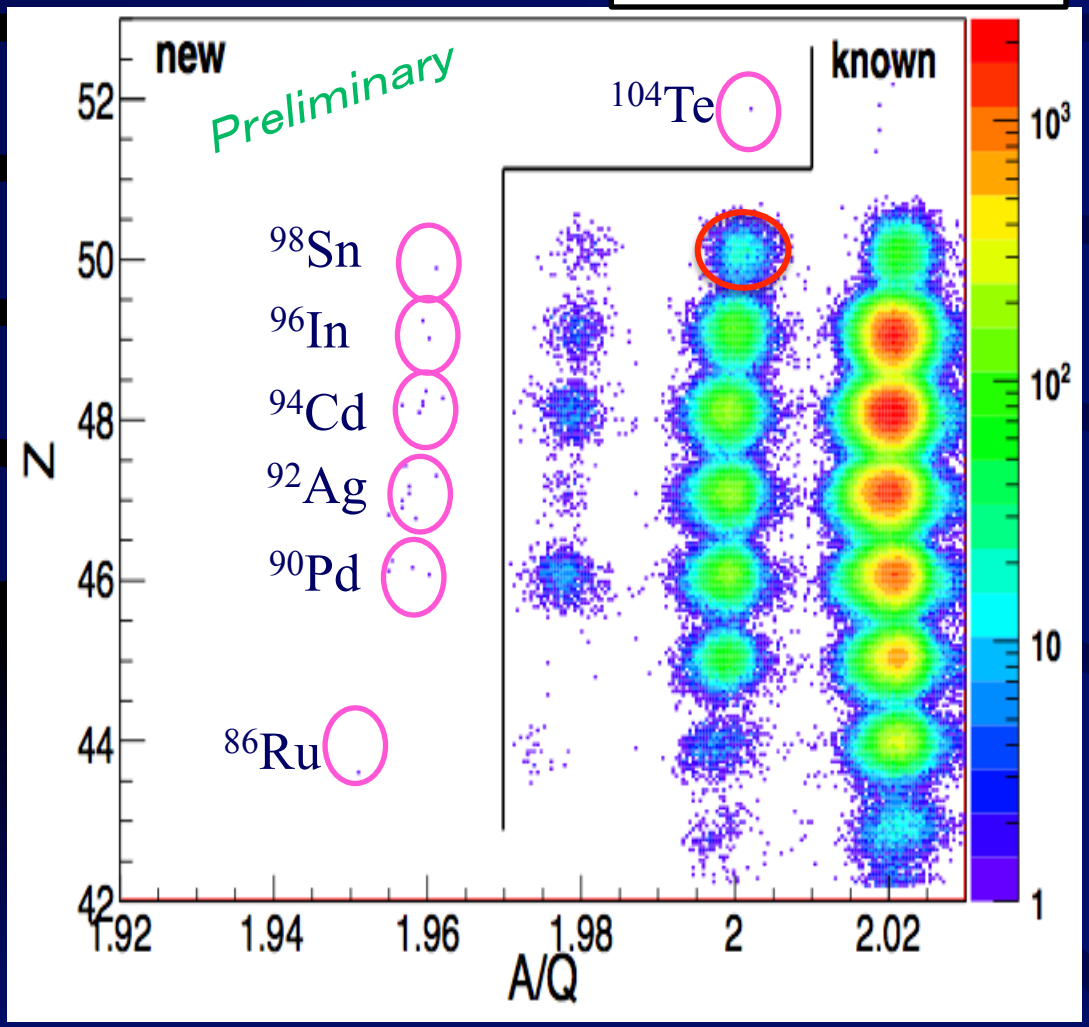
Decay Spectroscopy in vicinity of ^{100}Sn (Z=50, N=50)

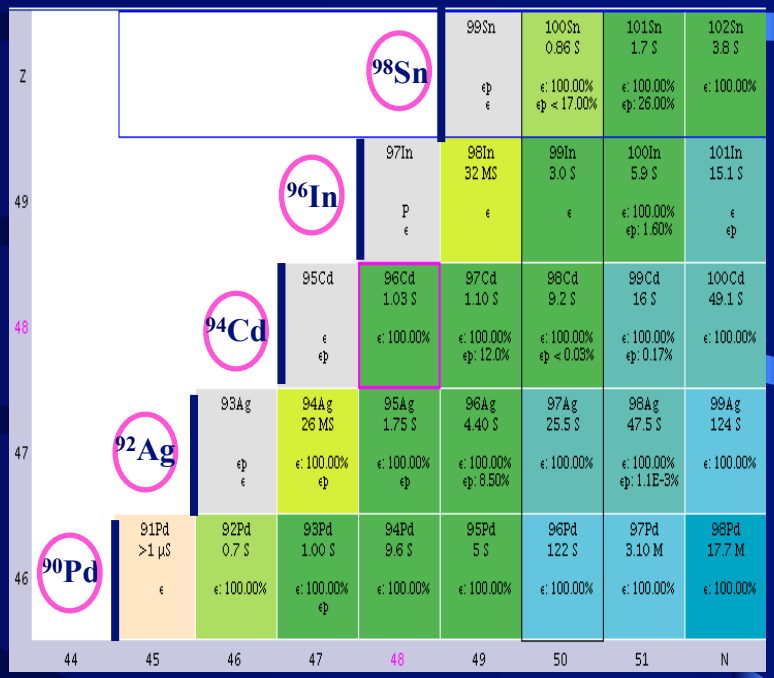
^{124}Xe beam int. = 32~ 38 pnA

M.Lewitwicz, R.Krucken/R.Gernhauser, SN

^{100}Sn ~ 2280 events

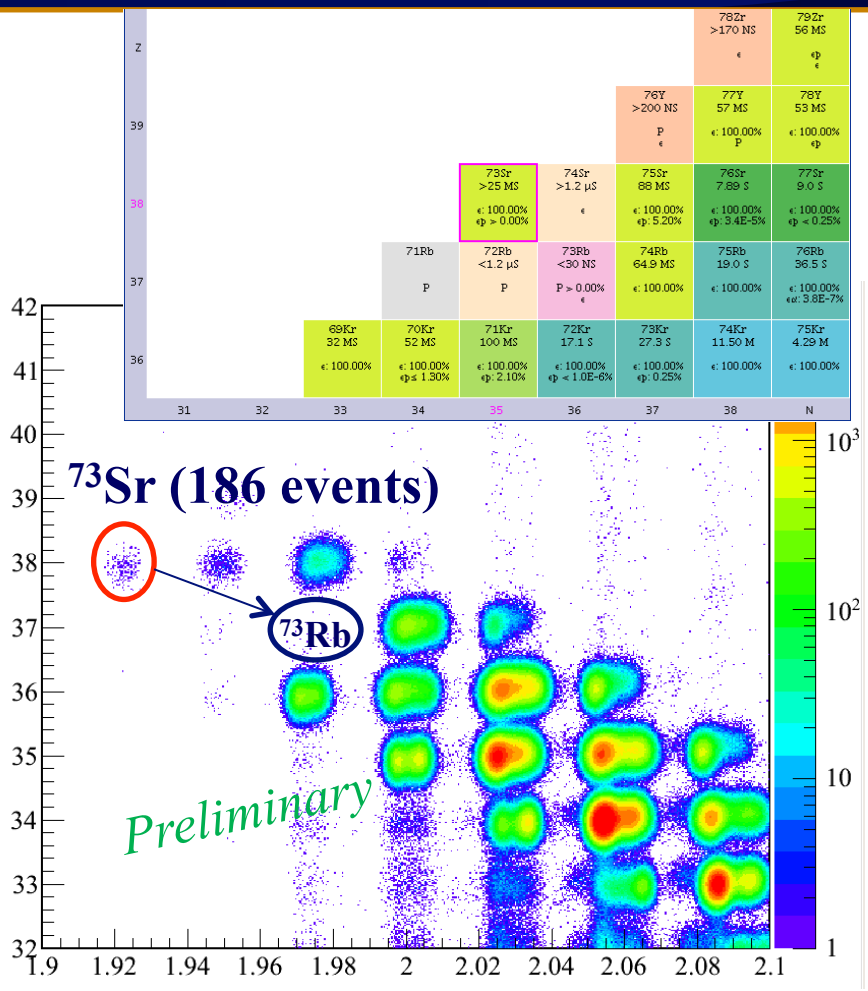
PhD I.Celikovic @ GANIL



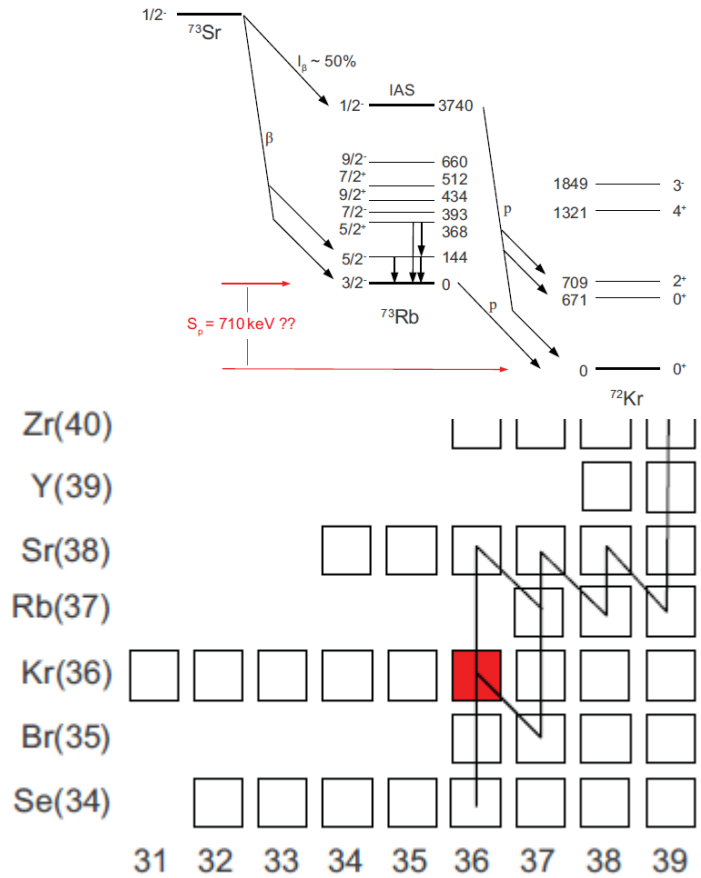


Half-lives: ^{99}Sn, ^{97}In, ^{95}Cd, ^{93}Ag ..
Qbeta: ^{100}Sn with higher statistics
Beta-delayed gamma
Beta-delayed proton

RIBF097: rp-process (G.Lorusso)



G.Lorusso (RIKEN) … 2.5 days

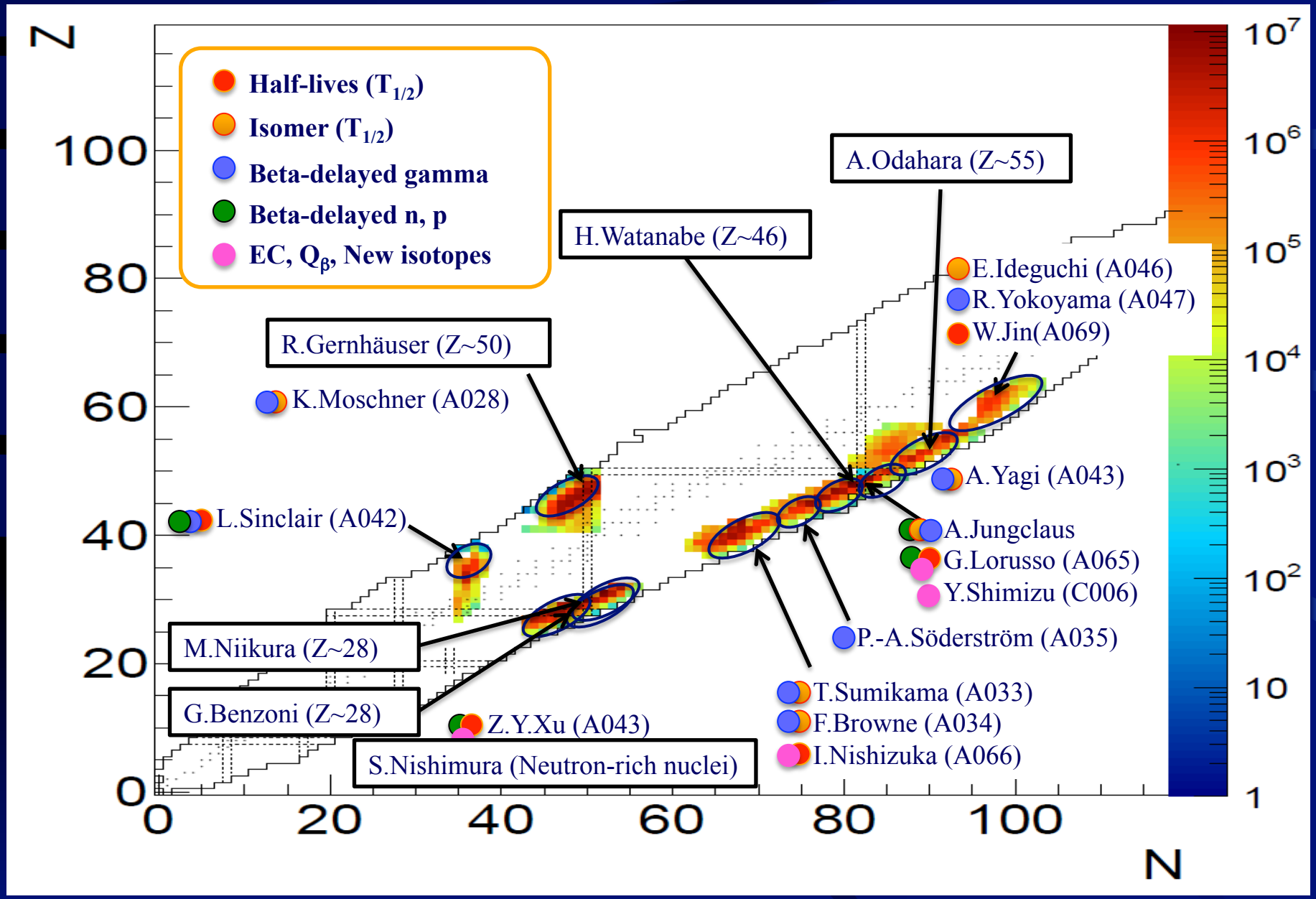


73Sr → 73Rb

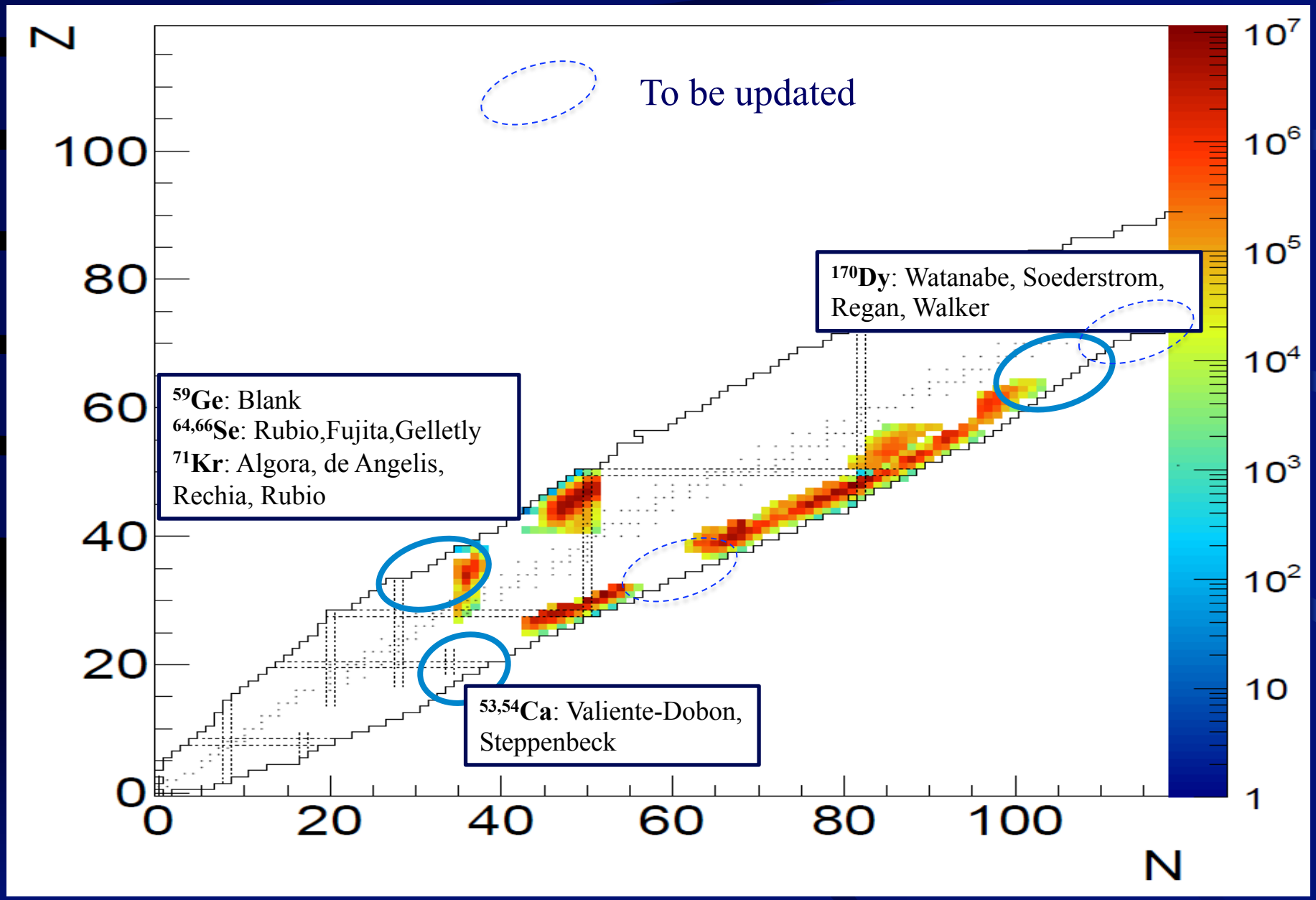
→ 72Kr + p … Energy spectrum of beta-delayed proton

… Beta-decay half-lives of ^{73,74}Sr (L.Scinclair @ York, G.Lorusso)

EURICA Contributions in Last ARIS2014 Conf. @ U.Tokyo



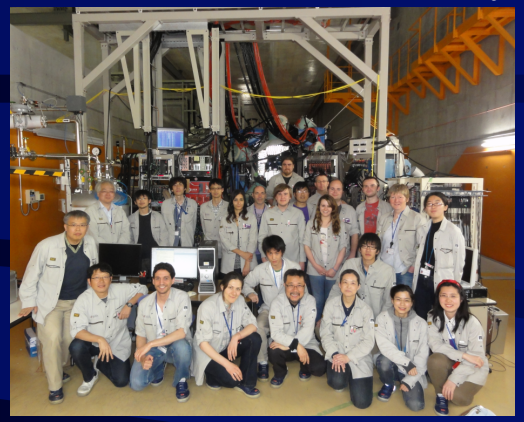
Remaining EURICA campaigns



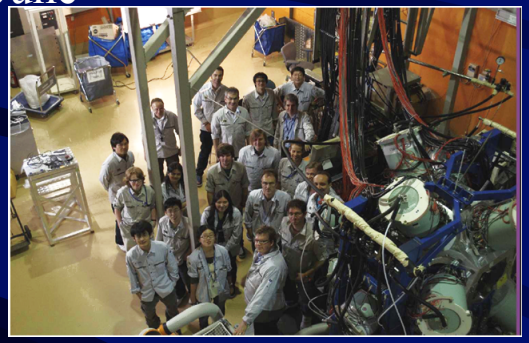
EURICA Collaboration and Support

2012 Nov.-Dec.

2013 May



2012 June



Acknowledgement:
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PreSPEC, GSI, IBS-RISP

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

- Decay spectroscopy is powerful tool to investigate the properties of exotic nuclei !
  - Beta-decay half-lives ($T_{1/2}$)
  - Beta-delayed gamma (low lying states), Isomer
  - Qbeta, EC
  - Beta-delayed neutron (proton) –emission
- Decay projects at RIBF
  - EURICA (beta-gamma)
  - BRIKEN (beta-neutron)
  - CAITEN (beta-gamma-neutron)

SEASTAR (In-Beam Gamma)
+
EURICA (Stop beam)

- High intensity radioactive beam facility
  - RIBF , FAIR, FRIB, GANIL, TRIUMF, ISOLDE, RISP, …

    → Golden time for nuclear structure & nuclear astrophysics

    (Magicity, Shell-quenching, Deformation

    → r-process, rp-process, …)

Decay Programs at RIBF

2009

2010

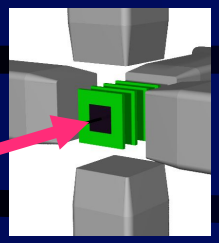
2011

2012

2013

2014

β-γ



^{110}Zr region
(3-days)

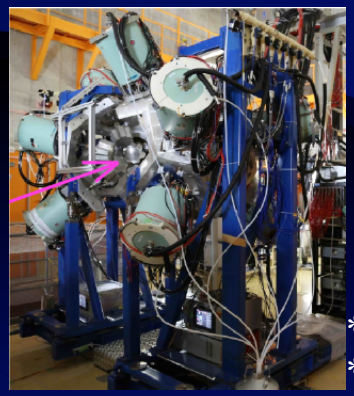
*PLB 696, 186 (2011)

*PRL. 106, 052502 (2011)

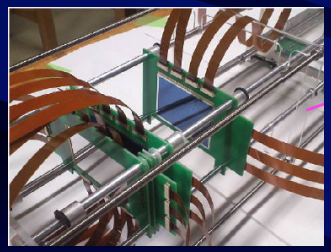
*PRL. 106, 202501 (2011)

*PLB 704, 270 (2011)

EURICA Project



WAS3ABi (Si)



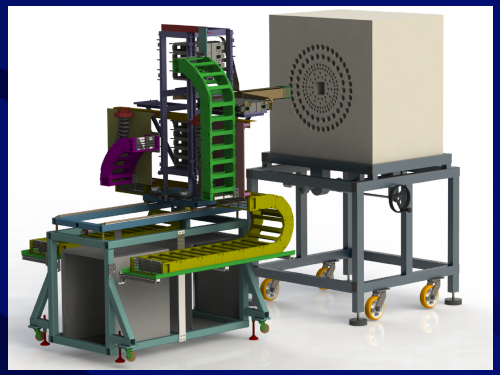
*PRC 88, 024301 (2013)
*PRL 111, 152501 (2013)
*PRL *** (2014)

β-n(-γ)
[high efficiency]

BRIKEN Project

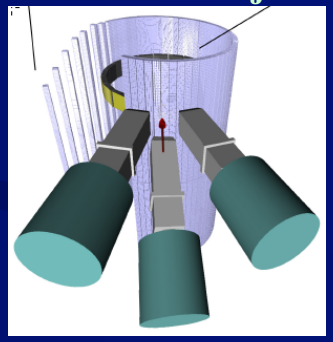
180 ^{3}He counters

BELEN (Spain)
+3Hen (ORNL)
+GSI/Russia+RIKEN

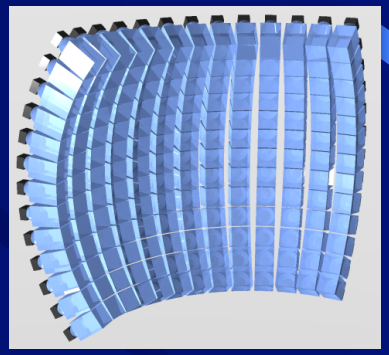


β-γ-n
[fast timing]

CAITEN Project



- LaBr3 detectors
- Neutron detector (NiGIRI)



Thank you.