
RIKEN
NISHINA
CENTER

Gamma-ray Spectroscopy Experiments at RIKEN

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ピーター　ドルネンバル

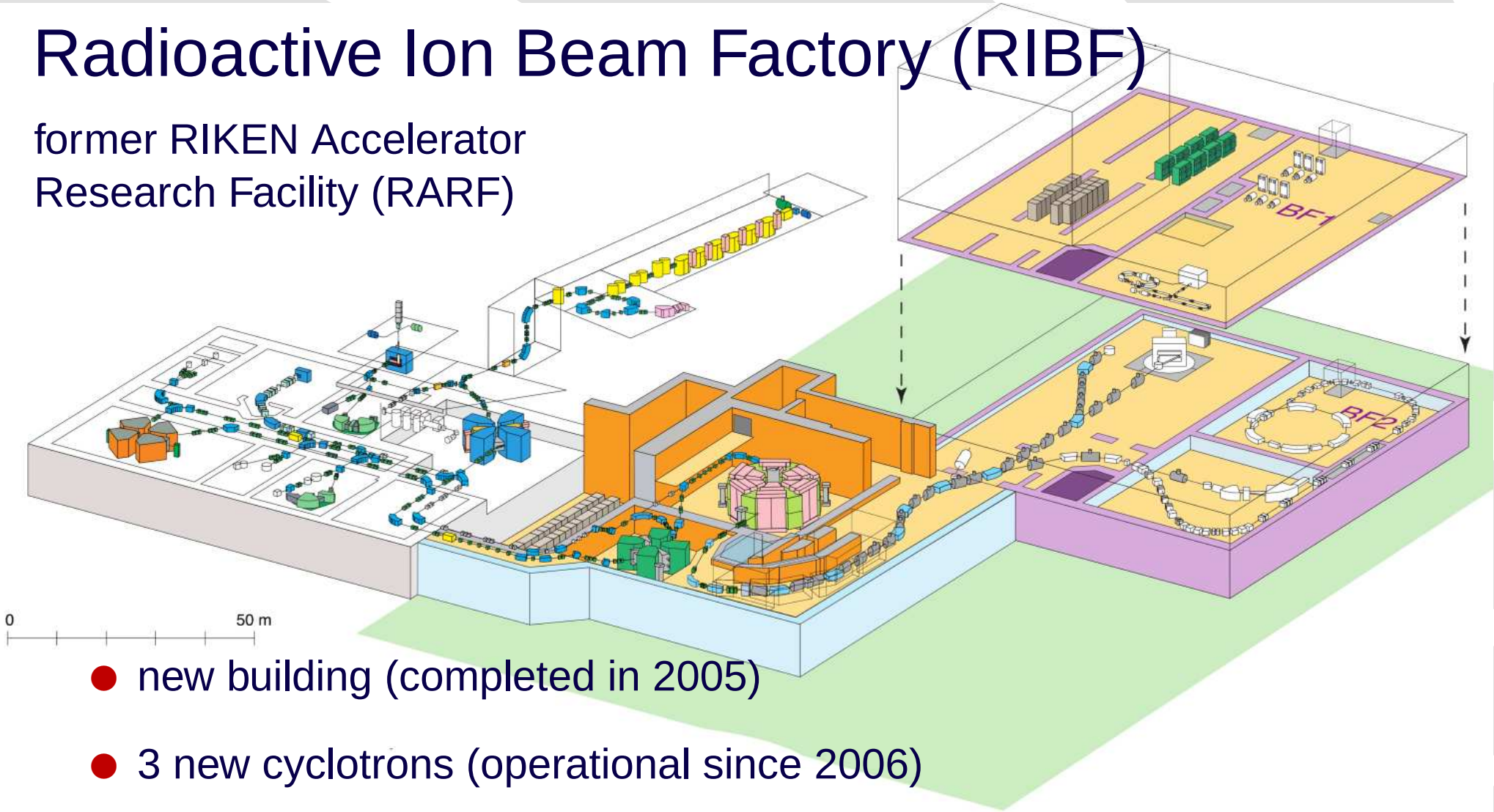
Outline

- RI beam production and separation at the RIBF
- In-beam γ-ray spectroscopy
  - ^{38}Mg
- Decay spectroscopy
  - $\beta - \gamma$ spectroscopy of neutron-rich Zr-Isotopes
  - EURICA

RI Beam Production at the RIBF

Radioactive Ion Beam Factory (RIBF)

former RIKEN Accelerator
Research Facility (RARF)



- new building (completed in 2005)
- 3 new cyclotrons (operational since 2006)

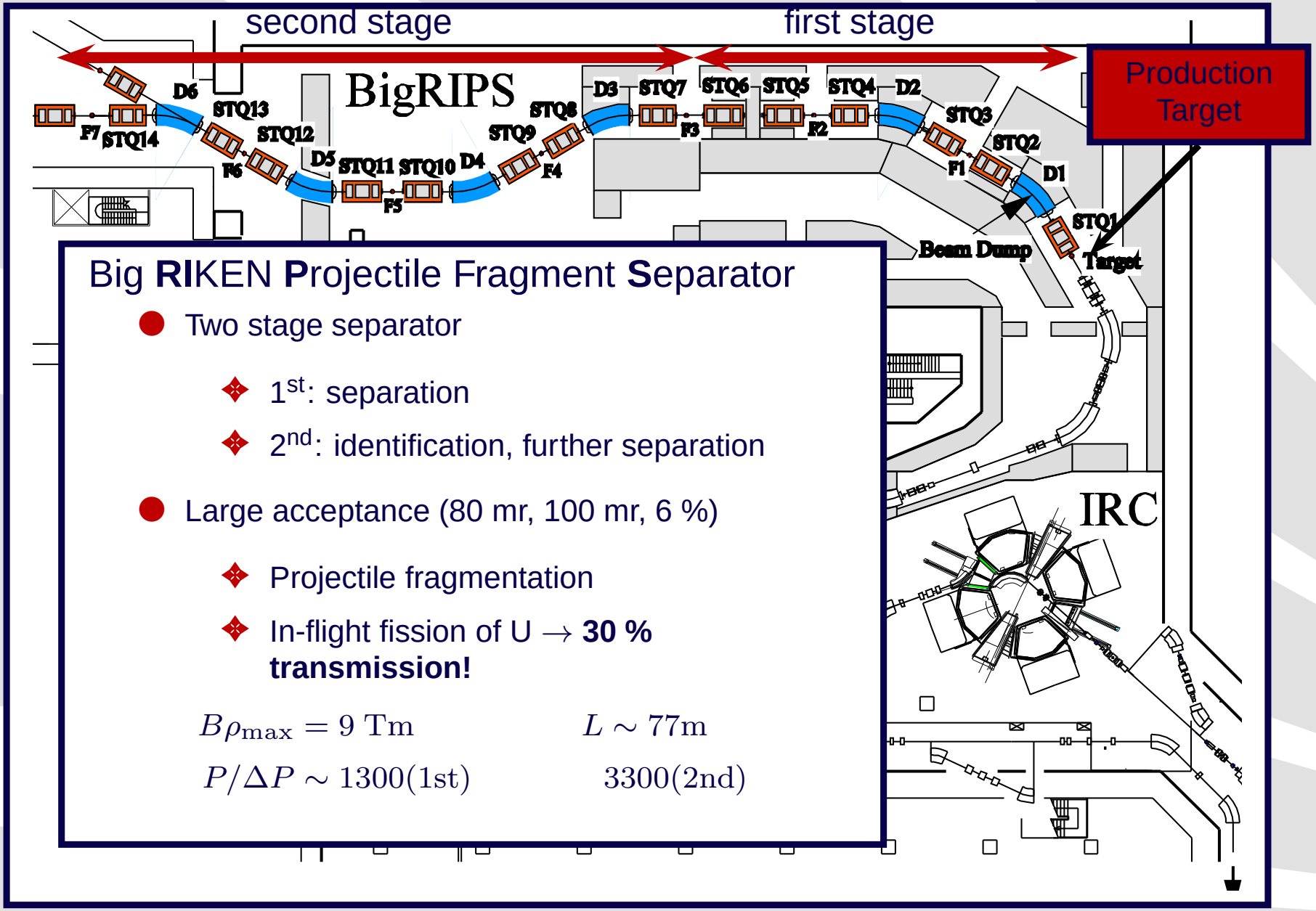
Superconducting Ring Cyclotron (SRC)

Intensities of 345 MeV/u beams from the SRC:

Nucleus	Beam Intensity / pnA	
	Achieved	Expected FY 2011/12
^{48}Ca	230	200
^{86}Kr	30	30
^{124,136}Xe	(10)	10
^{238}U	0.8	5

- $K = 2500$ MeV
- 8300 tons
- 5.36 m extraction radius
- 6 sector magnets
- four main RF cavities

BigRIPS Overview



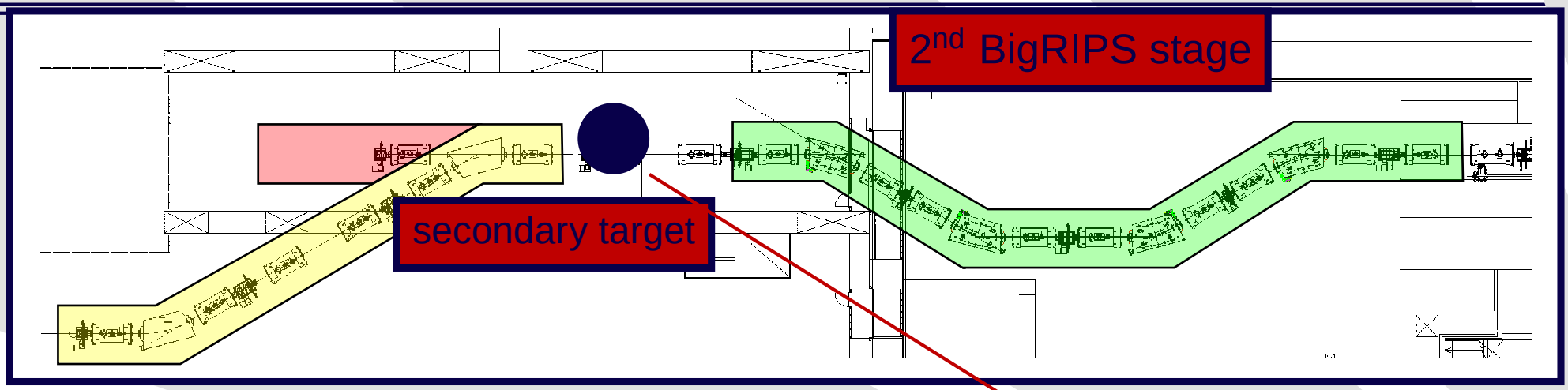
Big **RI**KEN **P**rojectile Fragment **S**eparator

- Two stage separator
  - 1st: separation
  - 2nd: identification, further separation
- Large acceptance (80 mr, 100 mr, 6 %)
  - Projectile fragmentation
  - In-flight fission of U $\rightarrow$ **30 % transmission!**

$B\rho_{\max} = 9$ Tm $\qquad L \sim 77$m

$P/\Delta P \sim 1300(1\text{st}) \qquad 3300(2\text{nd})$

ZeroDegree Spectrometer



~ 3 m between Q-poles

- DALI2 array, 186 NaI(Tl)
- GRAPE HPGe array
- $E_{\mathrm{beam}} \sim 100 - 250$ MeV/u

0° Spectrometer ZeroDegree

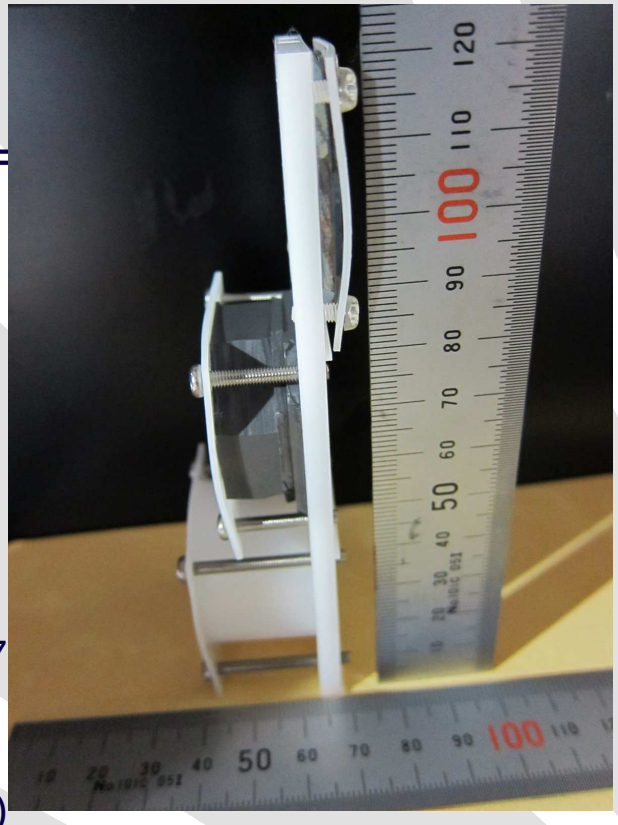
- **Particle ID** after secondary target
- Fragment momentum distribution
- Various modes of operation

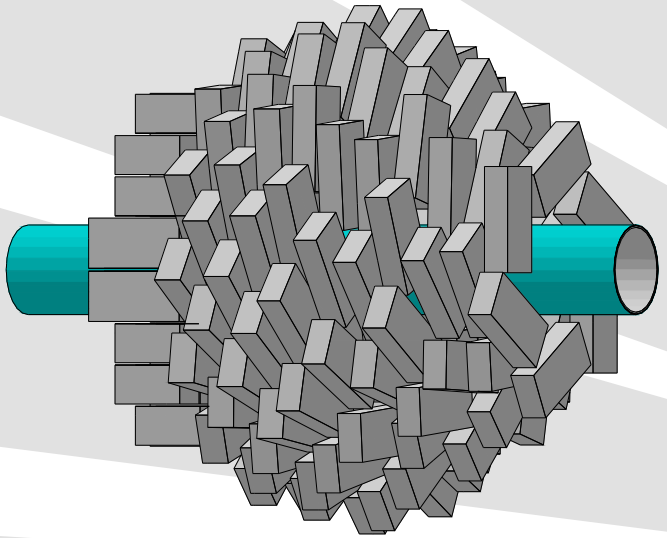
mode	$p/\Delta p$	Δp	Ang. Accep.
Large Accep.	1240	$\pm 3\%$	± 45 mrad(V) ± 30 mrad
High res.(achrom)	2120	$\pm 3\%$	± 20 mrad(V) ± 30 mrad(H)
Dispersive	4130	$\pm 2\%$	± 20 mrad(V) ± 30 mrad(H)

In-Beam Spectroscopy

DALI2

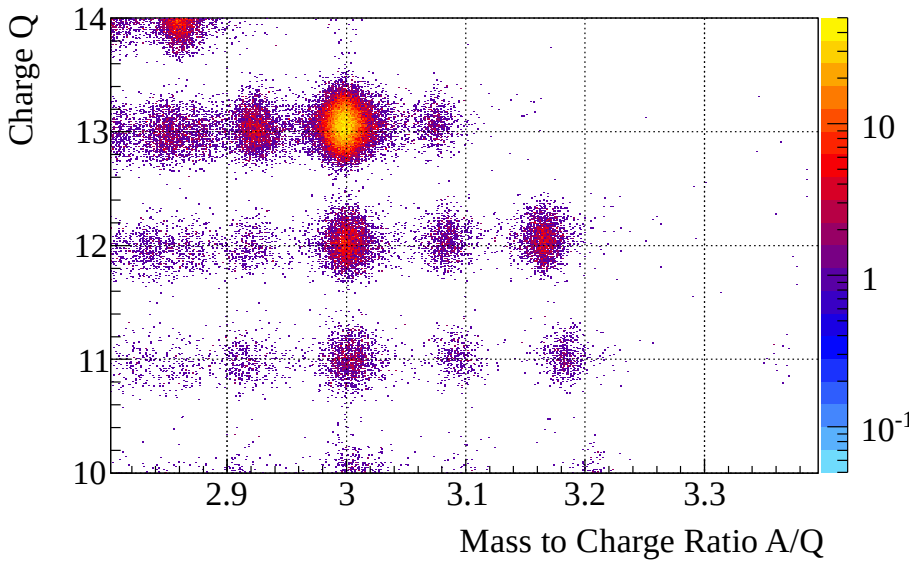
- 186 NaI(Tl) detectors
- ϑ coverage 11° to 165°
- $\Delta E/E$ ≈10(11) % (FWHM) at 100(250) MeV/u
- ≈ 20% FEP efficiency at 1 MeV
- Thick targets, 2.54 g/cm^2 C, 2.13 g/cm^2 CH_2, 3.37 g/cm^2 Pb
- S. Takeuchi *et al.*, RIKEN Pr. Rep. 36, 148 (2003)





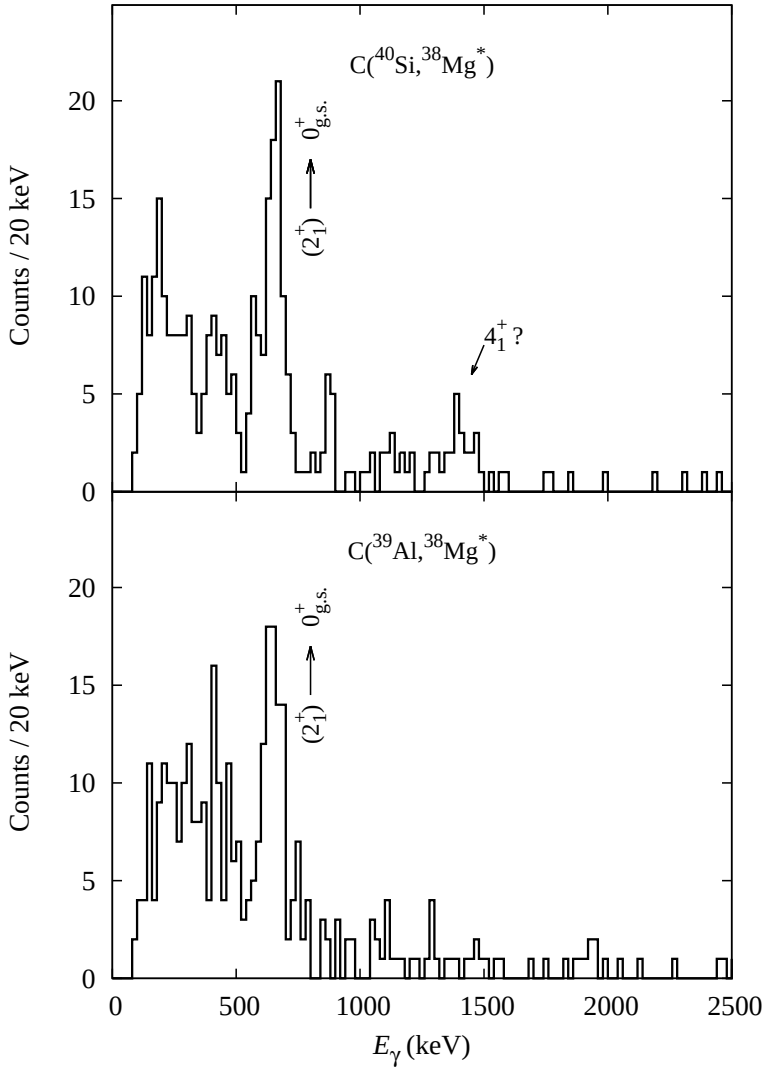
In-Beam Gamma-Ray Spectroscopy of ^{38}Mg

PID after F8



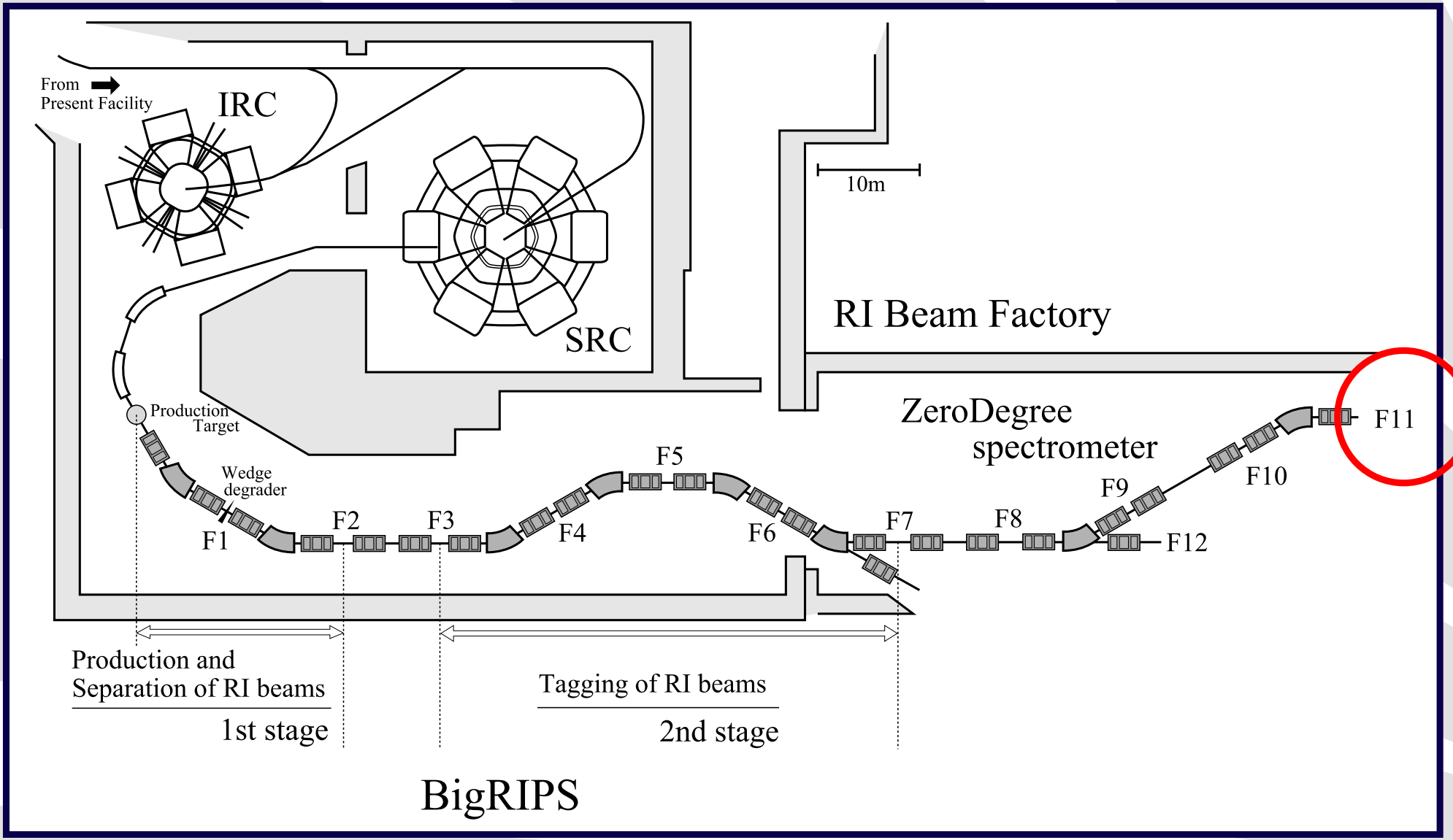
- ^{48}Ca, 70 pnA primary beam
- C(^{40}Si,^{38}Mg*), C(^{39}Al,^{38}Mg*)
- ^{40}Si: 3000 pps, 230 MeV/u
- F8 target: $^{nat.}$C, 2.54 g/cm^2
- $E(2_1^+)$ at 660(10) keV
- Total data taking: 14.7 hours

Doppler corrected γ-ray energy



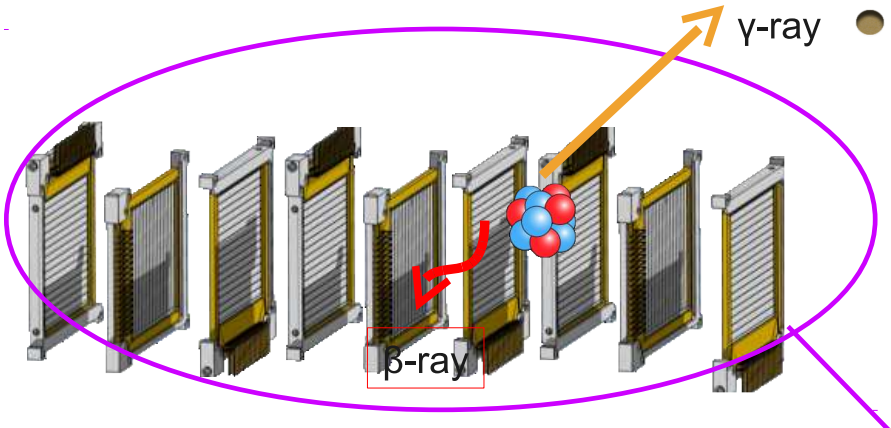
Decay Spectroscopy at the RIBF

Location for Decay Spectroscopy



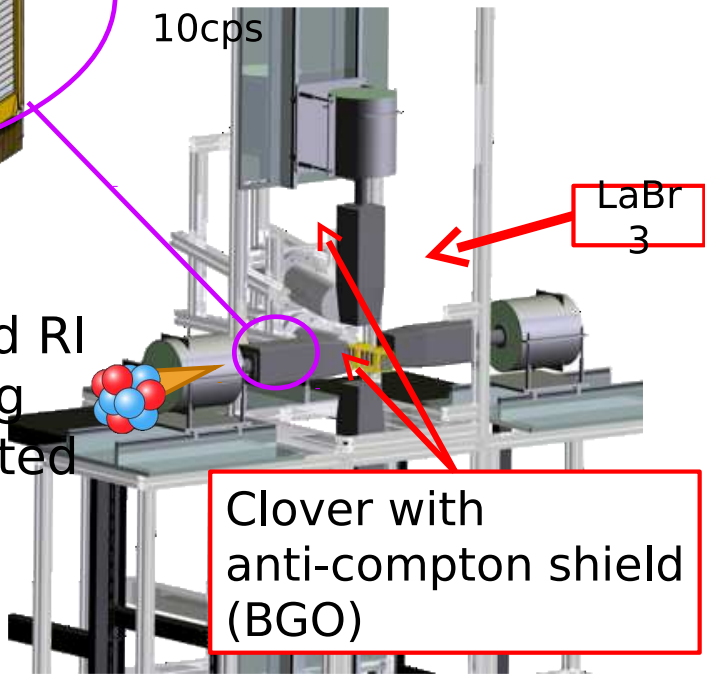
Experimental Setup

Detectors for β−γ spectroscopy



- RI & γ-ray detection
  - 9 DSSDs
  - ~ 2000 pixels in total
  - Implant rate ~ 100 cps
    T1/2 measurement : ~ 10cps

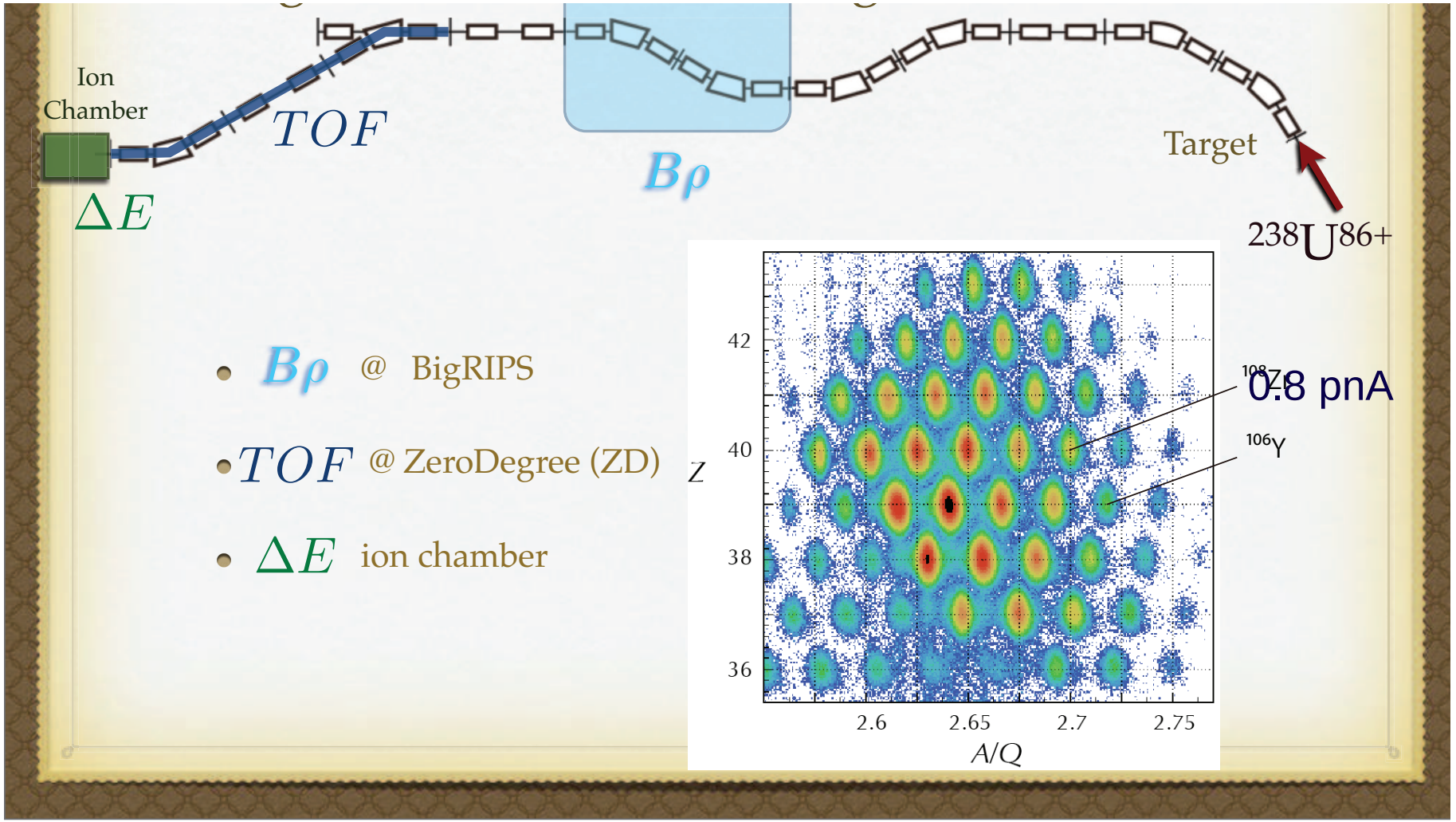
The implantation of an identified RI is associated with the following β-decay events that are detected in the same DSSD pixel



Y. Miyashita, Master

Onset of Large Deformation at $N = 60$

Production of Neutron-Rich Zr Isotopes



2011年5月27日金曜日

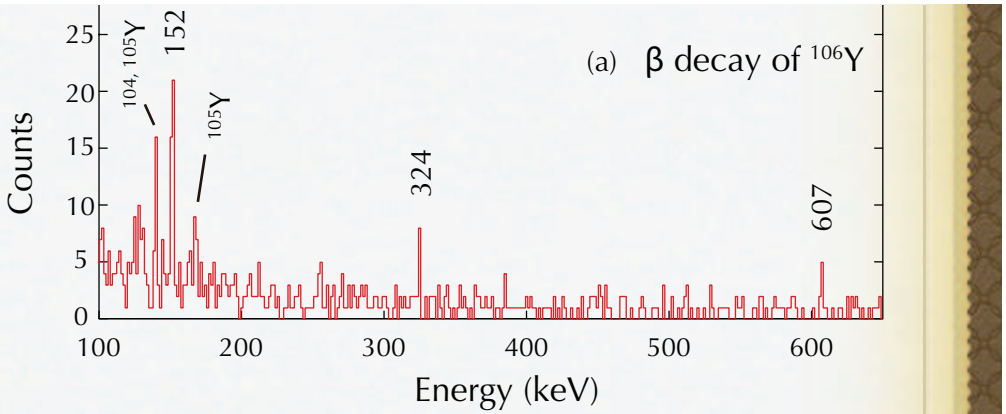
β-Delayed γ-ray in ^{106}Zr

- Spin assignment

  Most intense peak

  152 keV

  $2_1^+ \longrightarrow 0_1^+$



- Other peaks

  324 keV: $4_1^+ \longrightarrow 2_1^+$

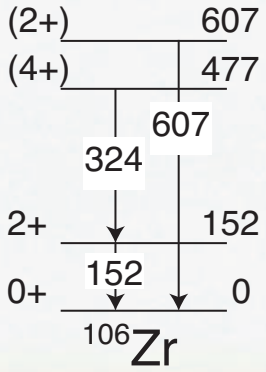
  607 keV: $2_2^+ \longrightarrow 0_1^+$

- Prediction (IBM)

  $E(4_1^+) = 455$ keV

  $E(2_2^+) = 618$ keV

S. Lalkovski and P. Vanlsacker, PRC 79, 044307 (2009).



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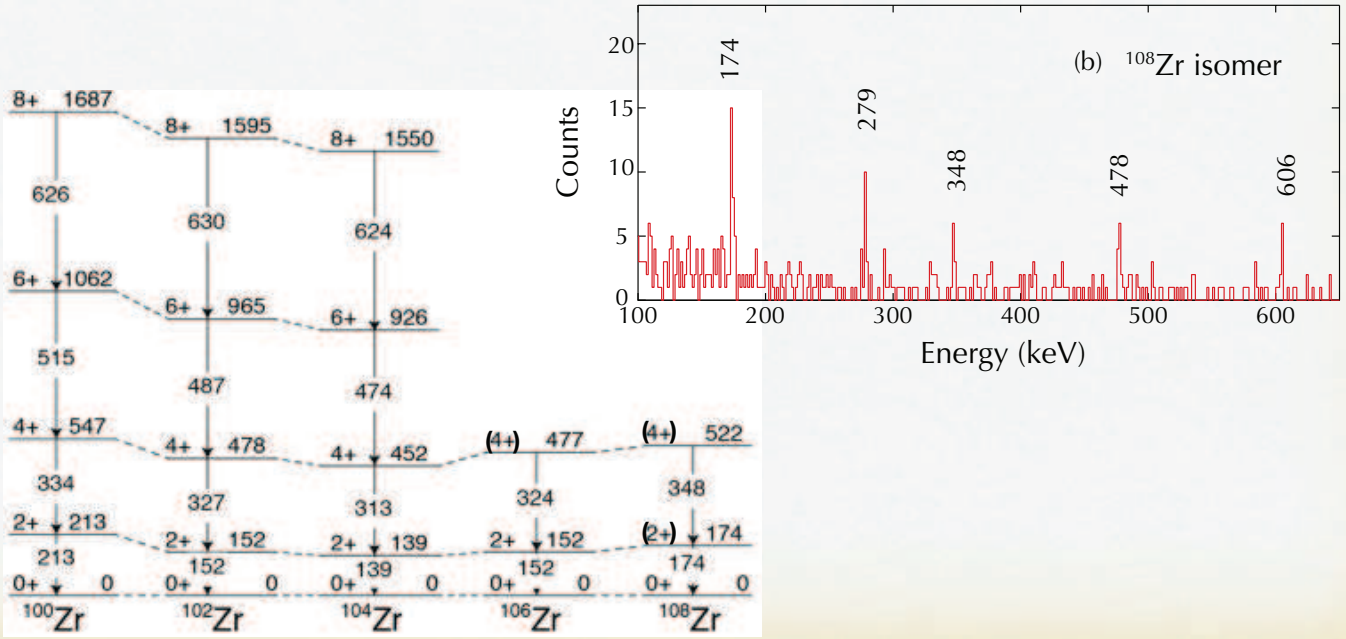
Isomeric State in ^{108}Zr

- Possible structure of ^{108}Zr

  Deformed as lighter Zr isotopes

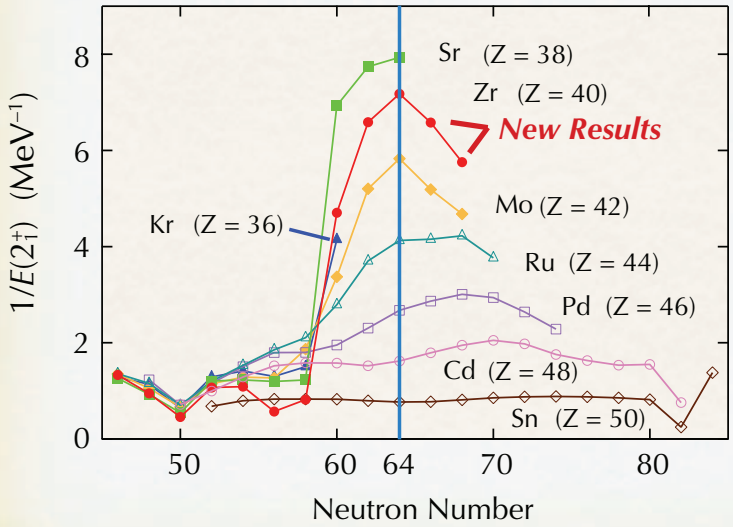
  Spherical due to possible N=70 subshell gap

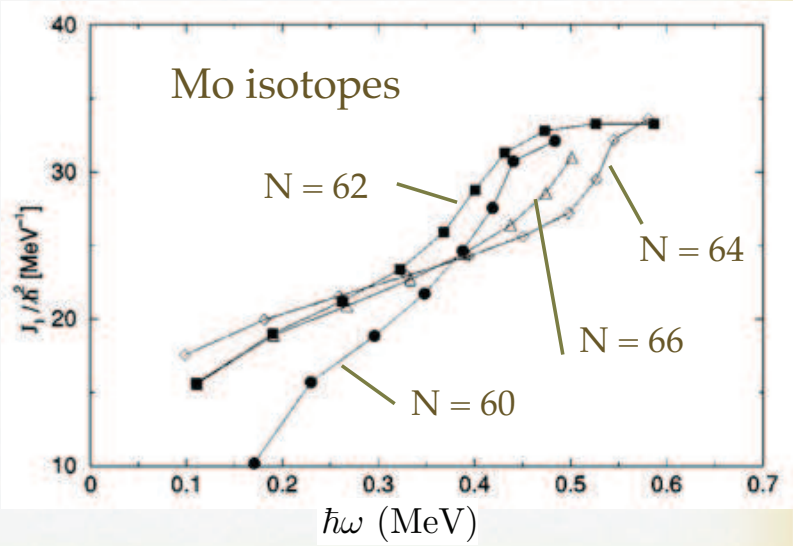


2011年5月27日金曜日

Systematics of Even-Even Nuclei

- Band crossing due to rotation alignment of $h_{11/2}$ neutron pair
  - Stability @ $\mathcal{N}$=64
    - **Deformed sub-shell closure @ N=64**





Hua et al., PRC 69, 014317 (2004)

2011年5月27日金曜日

T. Sumikama *et al.*, PRL **106**, 202501 (2011)

EURICA

What is EURICA?

EU ROBALL

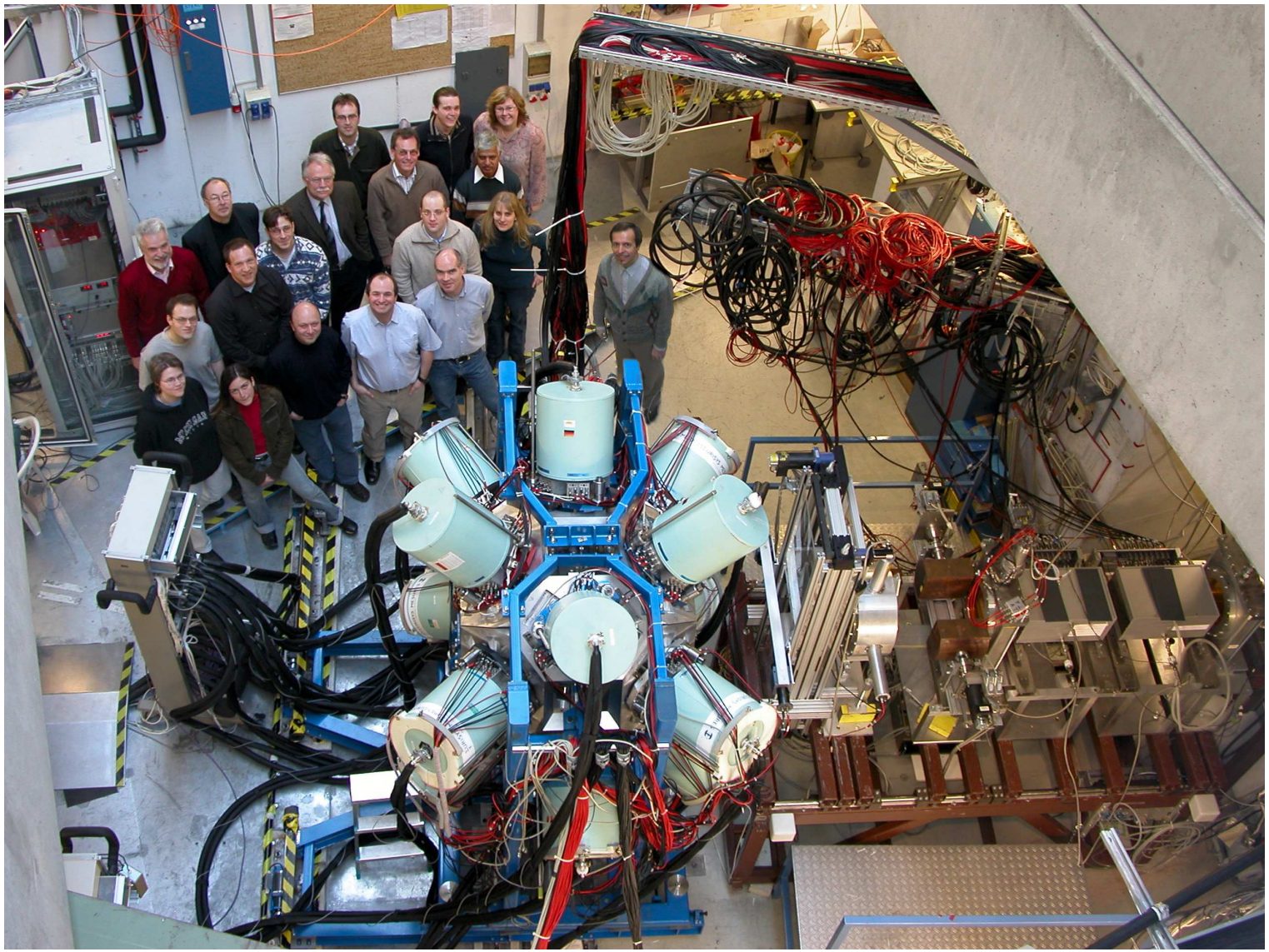
RI KEN

C luster

A rray

- Collaboration that wants to use the EUROBALL Cluster array in the stopped-beam configuration at RIKEN
- 15 Cluster detectors with RISING
  - 105 crystals
    - High granularity
    - 17 % photopeak efficiency at 662 keV

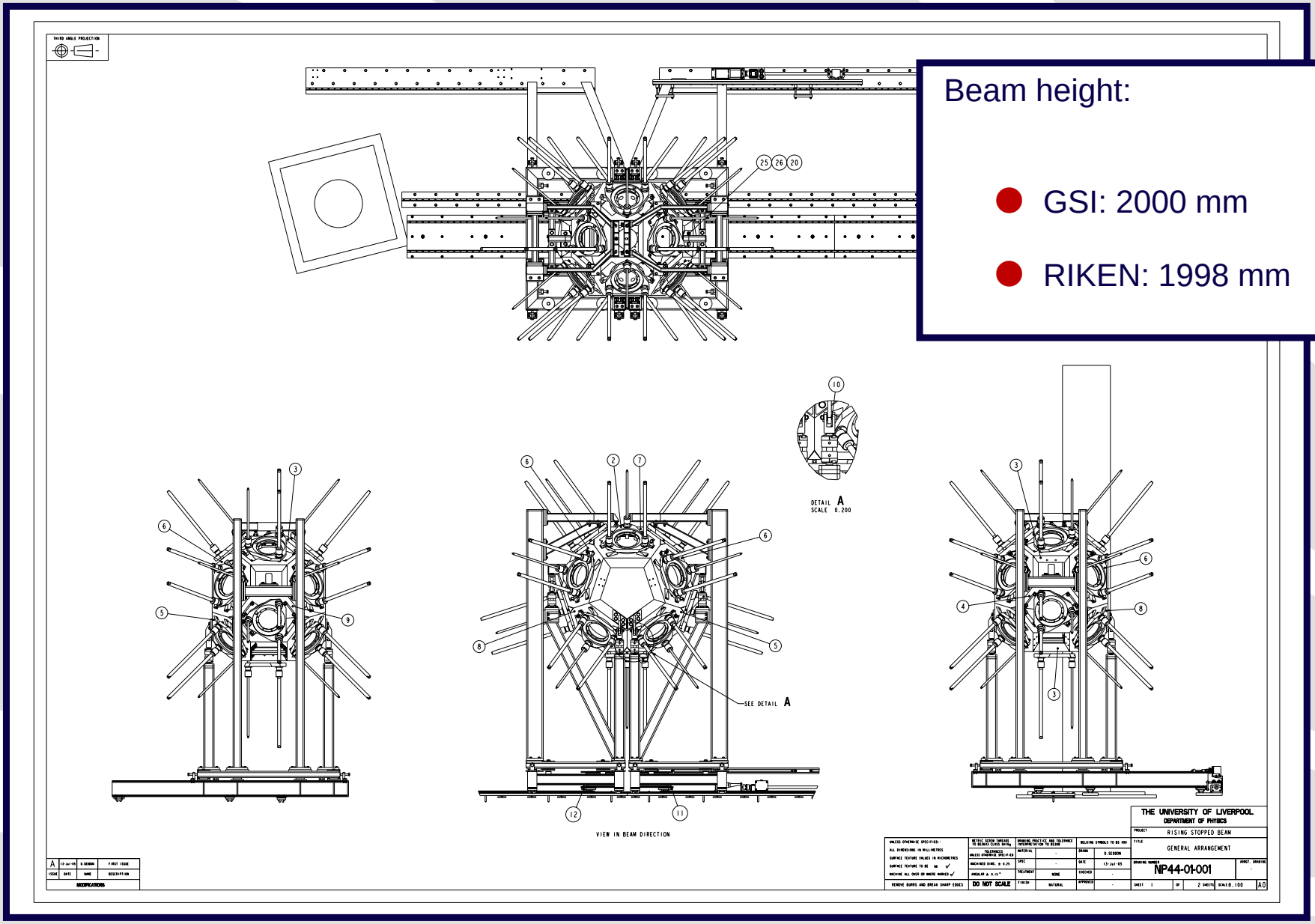
RISING Setup at GSI



1st EURICA WS May 23-24 2011

- Collaboration name: **EU**ROBALL **RI**KEN **C**luster **A**rray
- WS photo
- Physics case
  - Many new ideas proposed
  - Spokespersons of already approved decay experiments want to use EURICA
  - Submit set of proposals of **new and already approved** experiments to NP-PAC in Nov./Dec.
- Organizational structure
  - Collaboration board: 3 EU, 3 JP, (1 US)
- Work tasks

EURICA Frame



Beam height:

- GSI: 2000 mm
- RIKEN: 1998 mm

EURICA Collaboration

A. Algora[1], N. Aoi [2], H. Baba[3], G. Benzoni[4], N. Blasi[4], A. Bracco[4,5], S. Brambilla[4], F. Camera[4,5], I. Celikovic[6,7], J. Chiba[19], F. Crespi[4,5], G. de Angelis[8,9], G. de France[6], P. Doornenbal[3], A. Gadea[1], A. Garnsworthy[10], W. Gelletly[16], J. Gerl[11], R. Gernhäuser[12], A. Gottardo[8,9], G. Hackman[10], T. Hayakawa[26], Ch. Hinke[12], Y. Hirayama[27], H. Hua[25], Y. Ichikawa[3], E. Ideguchi[13], N. Imai[27], H. Ishiyama[27], T. Isobe[3], S. Jeong[27], A. Jungclaus[14], T. Komatsubara[22], R. Krücken[10], N. Kurz[11], J. Lee[3], S. Leoni[4,5], M. Lewitowicz[6], Z.H. Li[3,25], X. Li[25], G. Lorusso[3], R. Lozeva[15], D. Mengoni[8,9], B. Million[4], H. Miyatake[27], V. Modamio[8,9], K. Morimoto[3], T. Motobayashi[3], T. Nagatomo[3,23], T. Nakamura[21], T. Nakao[3], D. Napoli[8], M. Niikura[20], H. Nishibata[2], M. Nishimura[3], S. Nishimura[3], A. Odahara[2], S. Pietri[11], Zs. Podolyak[16], M. Ramdhane[17], F. Recchia[9], P. Regan[17], B. Rubio[1], E. Sahin[8,9], M. Sako[24], H. Sakurai[3], H. Schaffner[11], H. Scheit[18], P. Shury[3], G. Simpson[17], T. Sonoda[3], K. Steiger[12], D. Steppenbeck[3], T. Shimoda[2], T. Sumikama[19], J. Takatsu[2], S. Takeuchi[3], G. Thiamova[17], H. Ueno[3], J. Valiente Dobon[8,9], D. Verney[20], Y. Wakabashi[26], T. Wakui[28], H. Watanabe[3], Y. Watanabe[27], O. Wieland[4], H.J. Wollersheim[11], Z. Xu[3], H. Yamaguchi[13], Y. Ye[25], A. Yoshimi[3], and K. Yoshinaga[19]

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[26] JAEA, Japan
[27] KEK, Japan
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Summary and Outlook

Summary and Outlook

- Beam time at the RIBF is organized in campaigns
- $E(2_1^+)$ of ^{38}Mg at 660(10) keV
- First Decay spectroscopy performed at the RIBF in Dec. 2009
- Large interest to perform experiments with EURICA
- First campaign could start in April 2012

THE END

RI Beam Production at the RIBF

In-Beam Spectroscopy

Decay Spectroscopy

EURICA

Summary and Outlook

Backup slides from now