# The EURICA Project at RIKEN

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SLIDES from
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# *What is EURICA?*

**EU** ropean

**RI** KEN

**C** luster

**A** rray


- Collaboration that uses the Cluster array at RIKEN

# The EURICA project

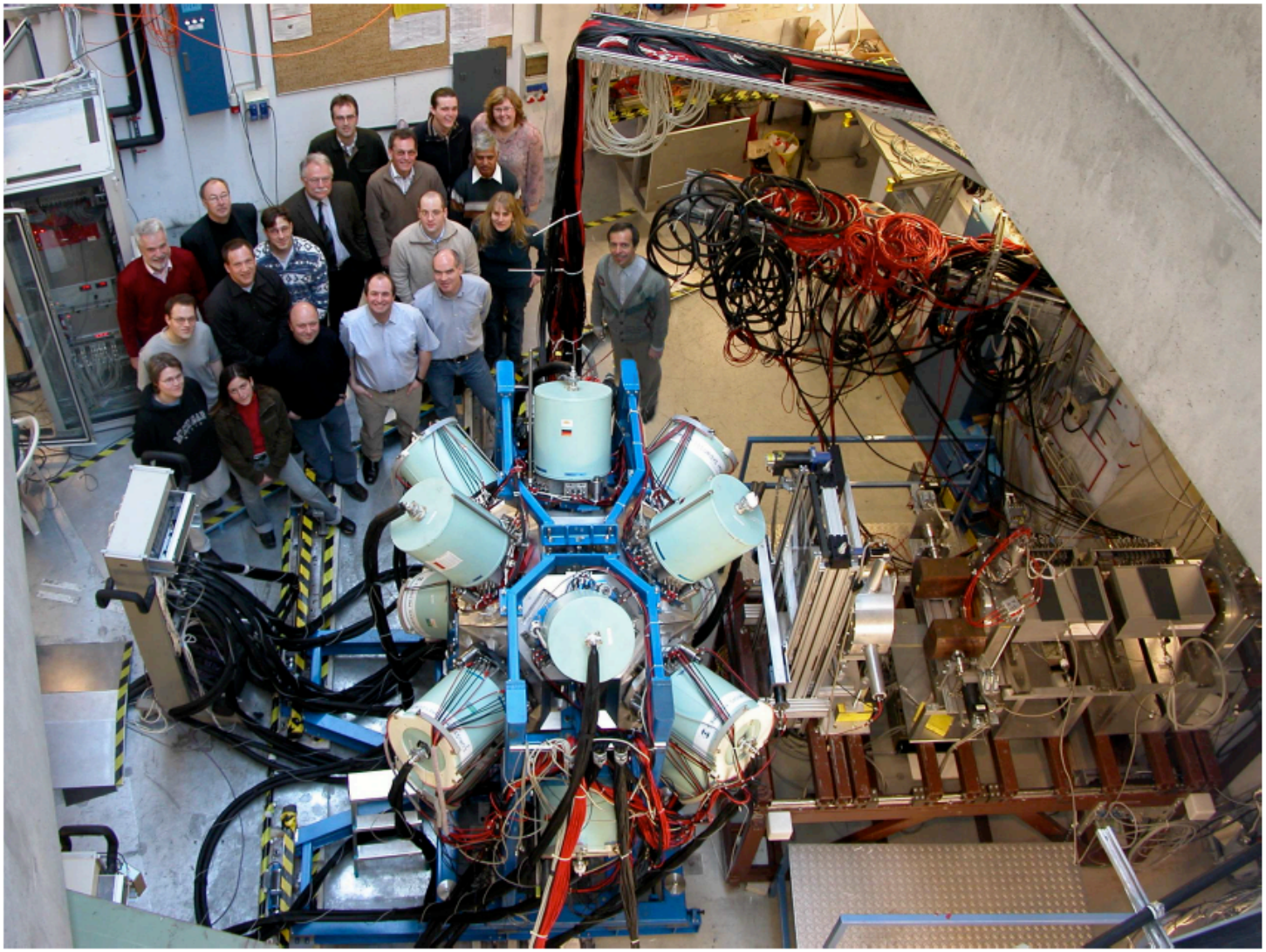
- γ-ray spectroscopy
  - Excited states
  - Fast timing
- β-decay studies
  - Half-lives
  - Q-values
  - β-delayed γ-rays
- HPGe detector array
- Silicon detector stack
- Plastic scintillator
- ($LaBr_3$ array)
- BigRIPS/ZeroDegree

# *Requirements for Effective Decay Spectroscopy of Exotic Nuclei*

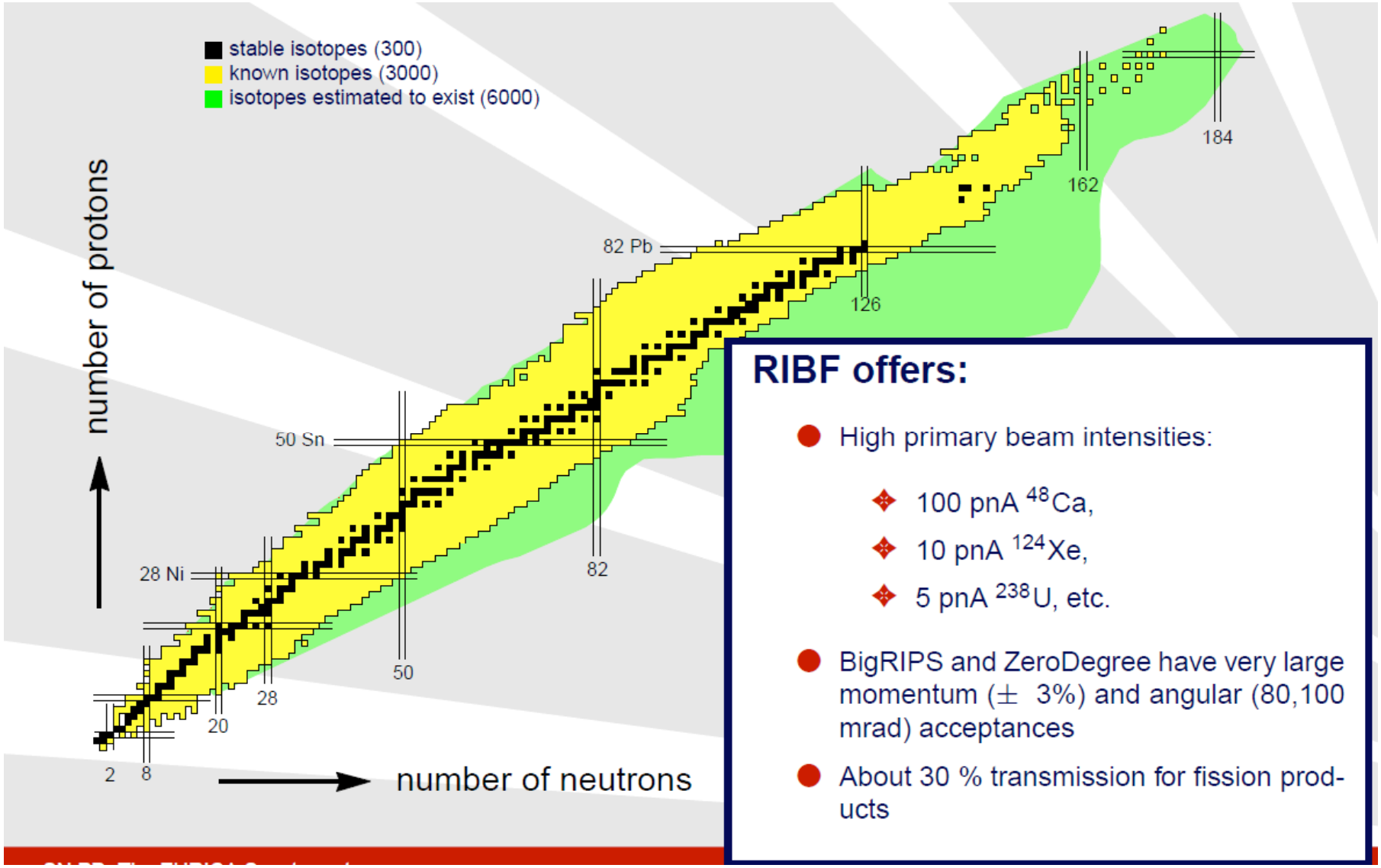
- High resolution
  - Distinction between close-lying $\gamma$-ray lines
- High efficiency
  - $\gamma$-$\gamma$ coincidences
- High granularity
  - Overcome "prompt"-flash problem
- Good ancillary detectors

  $\beta$-$\gamma$, direct timing, etc.

# RISING Setup at GSI



# Why Put EURICA at RIBF ?



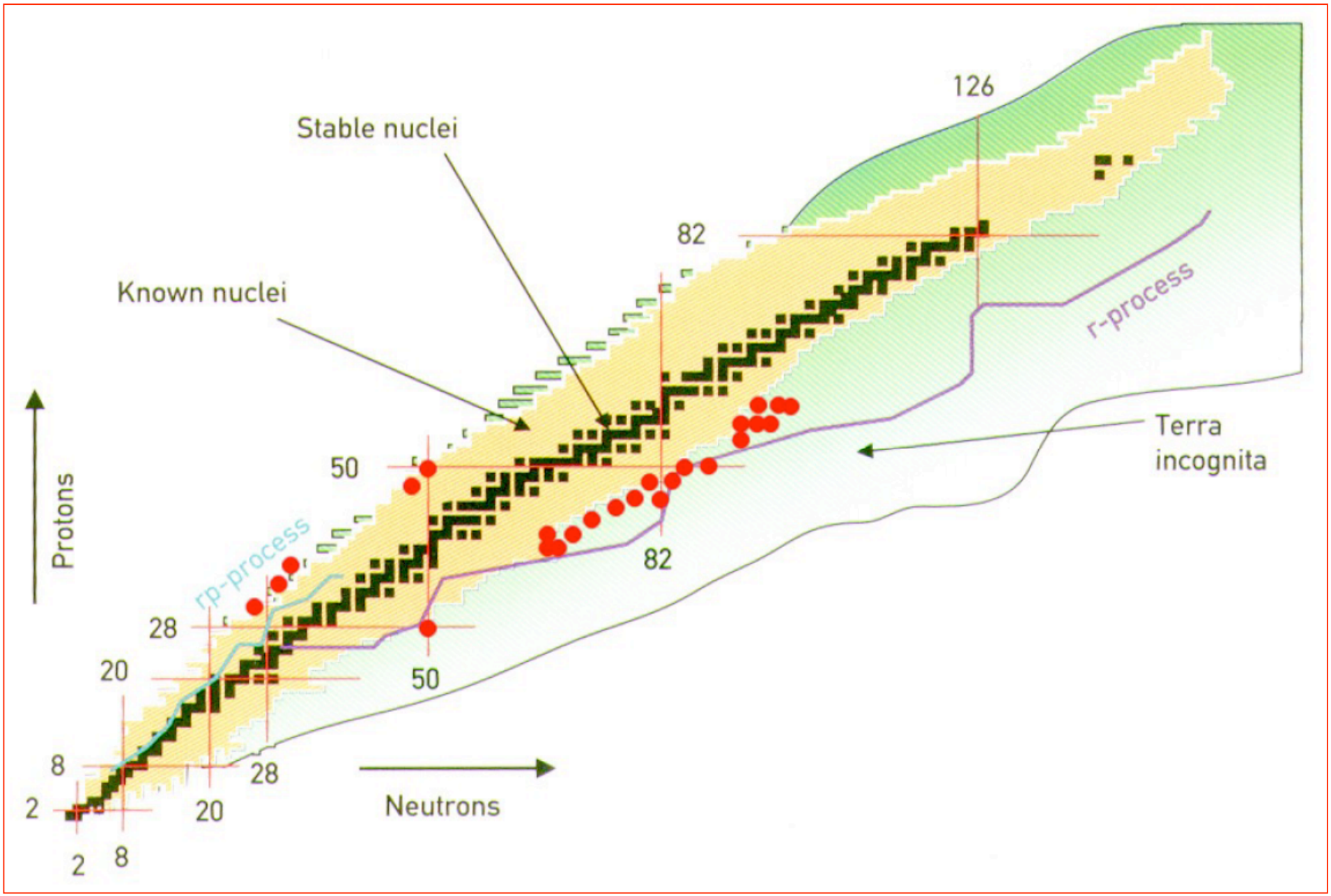

**RIBF offers:**

- High primary beam intensities:
  - 100 pnA $^{48}$Ca,
  - 10 pnA $^{124}$Xe,
  - 5 pnA $^{238}$U, etc.
- BigRIPS and ZeroDegree have very large momentum (± 3%) and angular (80,100 mrad) acceptances
- About 30 % transmission for fission products

# *Requirements for Effective Decay Spectroscopy of Exotic Nuclei*

- Need many Ge detectors
  - Not available at RIKEN
  - Collaborate:
    - Gammapool: Coordination of the resources for $\gamma$-ray spectroscopy in Europe $\rightarrow$ Cluster detectors
    - RISING/PreSpec $\rightarrow$ Support structure and electronics
    - TUM $\rightarrow$ SIMBA Si-array
    - Form new collaboration

# Regions to be studied by accepted EURICA proposed experiments

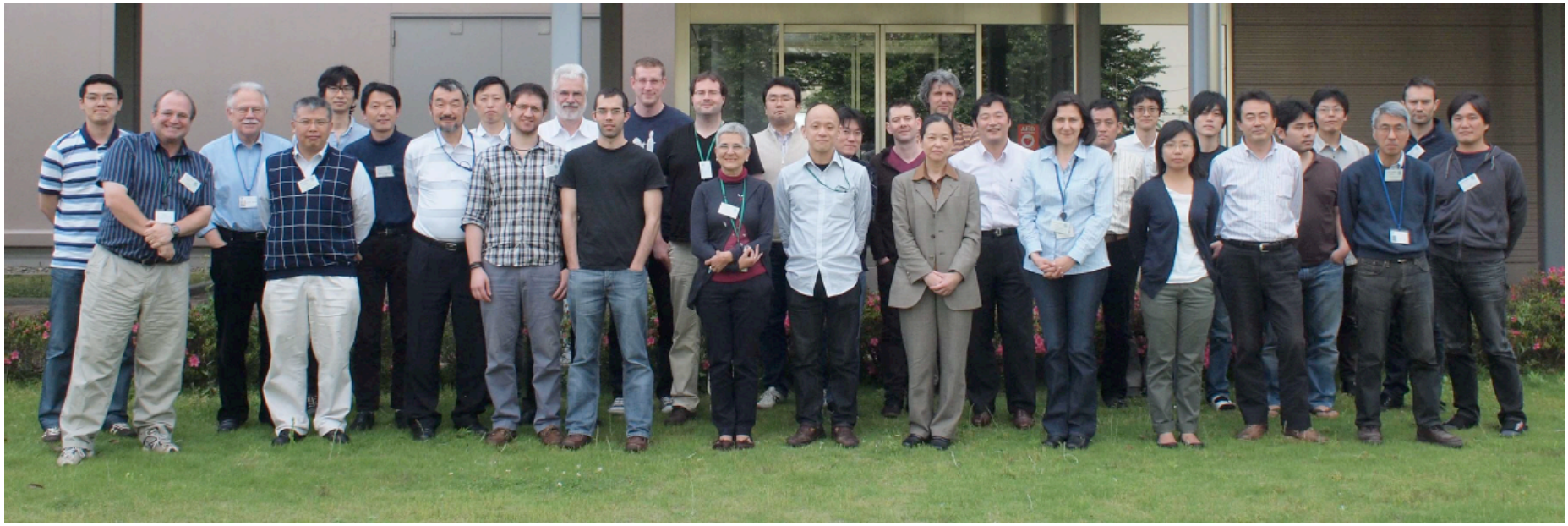


# *Cluster Detector Time-line:*

## *EUROBALL → RISING → PreSpec → E(U)RICA?*

- Laboratori Nazionali di Legnaro, Italy, 1997-1998
- Institut de Recherches Subatomiques, Strasbourg, France, 1999-2003
- GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2003-2011
  - RISING
    - Fast-Beam campaign, 2003-2005
    - g-RISING campaign, 2005
    - Stopped-Beam campaign, 2006-2009
  - PreSpec
    - Fast-Beam campaign, 2010-2011
    - Switch to AGATA in 2012

# EURICA Physics Workshop at RIKEN (23-24 May 2011)



http://indico.riken.jp/indico/contributionListDisplay.py?confId=423

# EURICA TIMELINE

- April 2011, Letter of Intent for EURICA Cluster detectors sent to Gammapool

- EURICA Physics workshop, held RIKEN, 23-24 May 2011 (http://indico.riken.jp/indico/contributionListDisplay.py?confId=423

- 27TH July 2011, Gammapool (Chair Rodi Herzberg) approves request from EURICA for 12 Cluster detectors including cyrostats (88 cluster capsules). Initial approval is until 30th June 2013

- EURICA Physics workshop, held at GSI, 12 September 2011 (https://indico.gsi.de/conferenceTimeTable.py?confId=1313#20110912 )

- First EURICA experiment ($^{124}$Xe beam) (Boutachkov, Wadsworth, Blazhev et al., from 18-25 June 2012)

- Detectors are "owned" by Gammapool Owners Committee (OC): Coordination of the resources for $\gamma$-ray spectroscopy in Europe $\rightarrow$ Cluster detectors
- Submitted EURICA project proposal to OC to host the Cluster detectors on July 1st

The Gammapool committee has discussed your EURICA bid at its meeting on July 27th. The project is supported by a rich and attractive physics case and the committee is impressed by the unique opportunities and the large support base that the project has gathered in a short period of time. We also note very positively the significant commitment by RIKEN in terms of beamtime, resourcing and manpower and we have no doubt that the project will reap large scientific rewards.

We therefore **approve,** conditional on the signing of an appropriate MoU, the following request:

a) 88 Cluster Capsules sufficient for 12 Cluster detectors, including 12 Cryostats
b) 88 HV elbows
c) 1 Manipulator
d) Specialist equipment for mounting/dismounting to be agreed with GSI

The committee **approves** this loan for use until June 30th 2013. The items listed under b,c and d need to be agreed with the homebase of the Cluster detectors, GSI. Full records of assembly, test and repair are standard conditions of any loan and will form a part of the MoU. Good communication between the EURICA and PRESPEC campaign managers will be essential.

We ask to be kept informed of the progress of the project and will ask for an update by July 1st of every year, which should include a list of publications and PhD theses based on the use of Gammapool resources. We also ask that the use of Gammapool resources is acknowledged in all appropriate publications.

Yours sincerely

R-D Herz

Rolf-Dietmar Herzberg
Chairman Gammapool OC

# EURICA Collaboration


A. Algora[1], N. Aoi[2], H. Baba[3], T. Bäck[4], Ch. Bauer[37], G. Benzoni[5], N. Blasi[5], M. Bostan[6], A. Bracco[5,7], S. Brambilla[7], A. Bruce[44], L. Cáceres[8], B. Cakirli[39], F. Camera[5,7], W.N. Catford[18], I. Celikovic[8,9], J. Chiba[10], E. Clément[8], F. Crespi[5,7], P.V. Cuong[46], G. de Angelis[11,12], G. de France[8], N. de Séréville[13], F. Didierjean[14], Zs. Dombradi[40], C. Domingo-Pardo[1], M. Doncel[15], P. Doornenbal[3], G. Duchêne[14], N. Erduran[16], Th. Feastermann[20], E. Farnea[11,12], S. Franchoo[13], Y. Fujita[2], A. Gadea[1], U. Garg[50], A. Garnsworthy[17], W. Gelletly[18], J. Gerl[19], R. Gernhäuser[20], S. Go[21], A. Gottardo[11,12], S. Grévy[22], G. Hackman[17], F. Hammache[13], T. Hayakawa[23], Ch. Hinke[20], Y. Hirayama[24], H. Hua[25], L.T.Q. Huong[46], T. Huyuk[1], F. Ibrahim[13], Y. Ichikawa[3], E. Ideguchi[21], N. Imai[24], N. Inabe[3], H. Ishiyama[24], T. Isobe[3], S. Jeong[24], A. Jungclaus[26], D. Kameda[3], L.H. Khiem[46], I. Kojouharov[19], K. Kolos[13], T. Komatsubara[27], A. Korichi[28], W. Korten[51], R. Krücken[17], T. Kubo[3], N. Kurz[19], A. Kusoglu[6], S. Lalkovski[47], F. Le Blanc[13], J. Lee[3], S. Leoni[5,7], M. Lewitowicz[8], Z.H. Li[3,25], X. Li[25], Zh. Li[41], M. Liu[42], W. Liu[41], Zh. Liu[43], G. Lorusso[3], R. Lozeva[14], S. Lunardi[11,12], P. Mason[16], I. Matea[13], D. Mengoni[11,12], C. Michelagnoli[11,12], B. Million[5], H. Miyatake[24], V. Modamio[11,12], C.B. Moon[29], K. Morimoto[3], T. Motobayashi[3], T. Nagatomo[3,30], T. Nakamura[31], T. Nakao[3], M. Nakhoshtin[16], D. Napoli[11], M. Niikura[13], H. Nishibata[32], M. Nishimura[3], S. Nishimura[3], F. Nowacki[14], J. Nyberg[33], A. Odahara[32], R. Orlandi[26], N. Pietralla[37], S. Pietri[19], A. Pipidis[11], Zs. Podolyak[18], B. Quintana[15], M. Ramdhane[34], F. Recchia[12], P. Regan[18], O. Roberts[44], B. Rubio[1], E. Sahin[11,12], M. Sako[3,35], H. Sakurai[3,36], H. Schaffner[19], H. Scheit[37], T. Shimoda[32], P. Shury[3,27], K. Sieja[14], G. Simpson[34], D. Sohler[40], T. Sonoda[3], O. Sorlin[8], I. Stefan[13], K. Steiger[20], D. Steppenbeck[3], T. Sumikama[10], B. Sunchan[48,49], H. Suzuki[3], J. Takatsu[32], H. Takeda[3], S. Takeuchi[3], D. Testov[13], G. Thiamova[34], J.C. Thomas[8], T.D. Trong[46], H. Ueno[3], C. Ur[11,12], Zs. Vajta[40], J. Valiente Dobon[11,12], D. Verney[13], Y. Wakabashi[23], T. Wakui[38], Y. Wang[41], H. Watanabe[3], Y. Watanabe[24], V. Werner[45], O. Wieland[5], H.J. Wollersheim[19], Z. Xu[36], M. Yalcinkaya[6], H. Yamaguchi[21], Y. Ye[25], A. Yoshimi[3], K. Yoshinaga[3,10], Y. Zhang[42], Y. Zheng[42], and X. Zhou[42]

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[10] Tokyo University of Science, Japan
[11] LNL, Legnaro, Italy
[12] University of Padova, Italy
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[14] IPHC, Strasbourg, France
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[17] TRIUMF, Vancouver, Canada
[18] University of Surrey, Guildford, UK
[19] GSI, Darmstadt, Germany
[20] TU München, Germany
[21] CNS, University of Tokyo, Japan
[22] CENBG Bordeaux, France
[23] JAEA, Tokai, Japan
[24] KEK, Tokai, Japan
[25] Peking University, China
[26] CSIC, Madrid, Spain
[27] University of Tsukuba, Japan
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[30] ICU, Tokyo, Japan
[31] Tokyo Institute of Technology, Japan
[32] Osaka University, Japan
[33] Uppsala University, Sweden
[34] LPSC Grenoble, France
[35] Kyoto University, Japan
[36] University of Tokyo, Hongo, Japan
[37] TU Darmstadt, Germany
[38] Tohoku University, Japan
[39] MPI Heidelberg, Germany
[40] ATOMKI, Debrecen, Hungary
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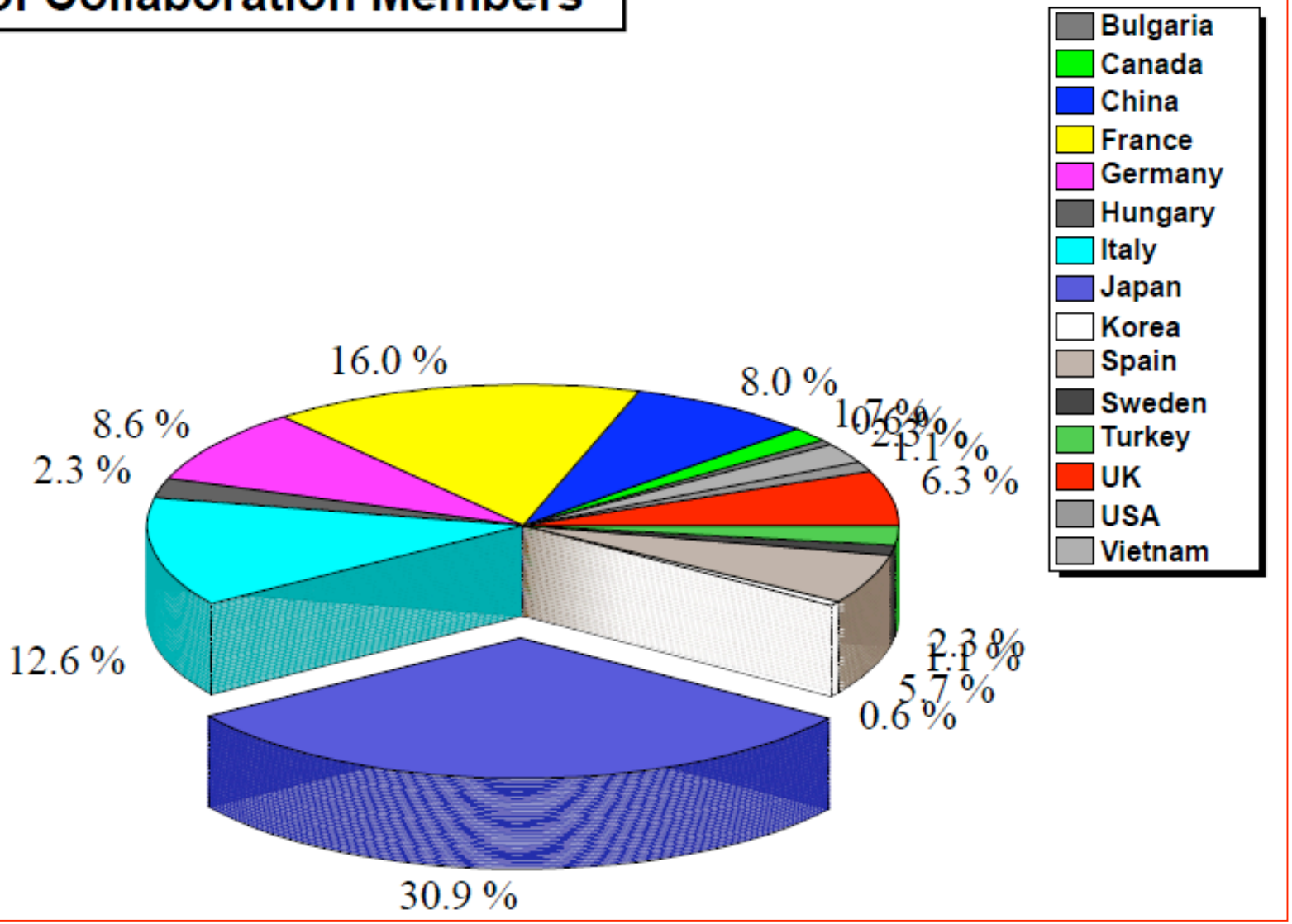
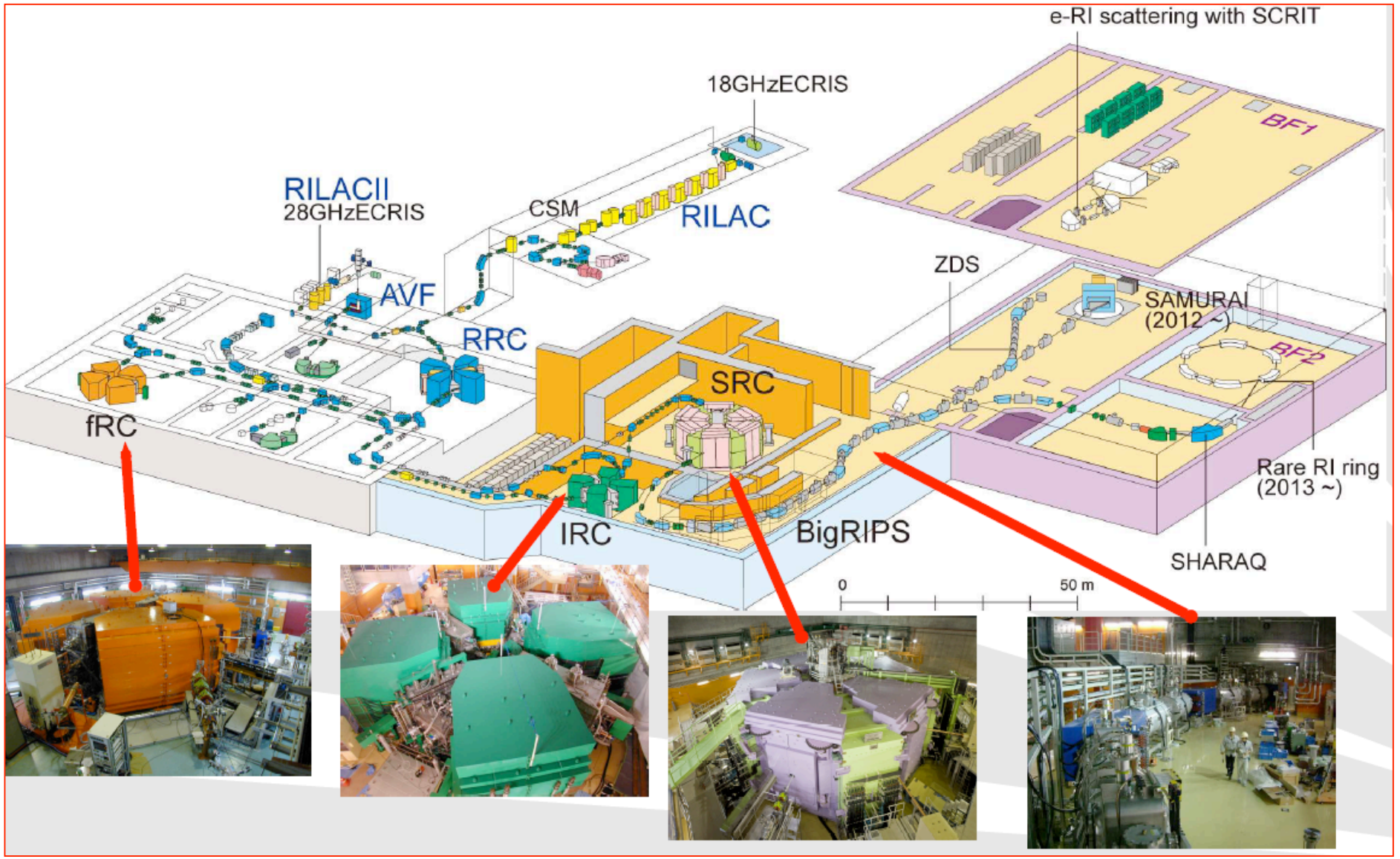
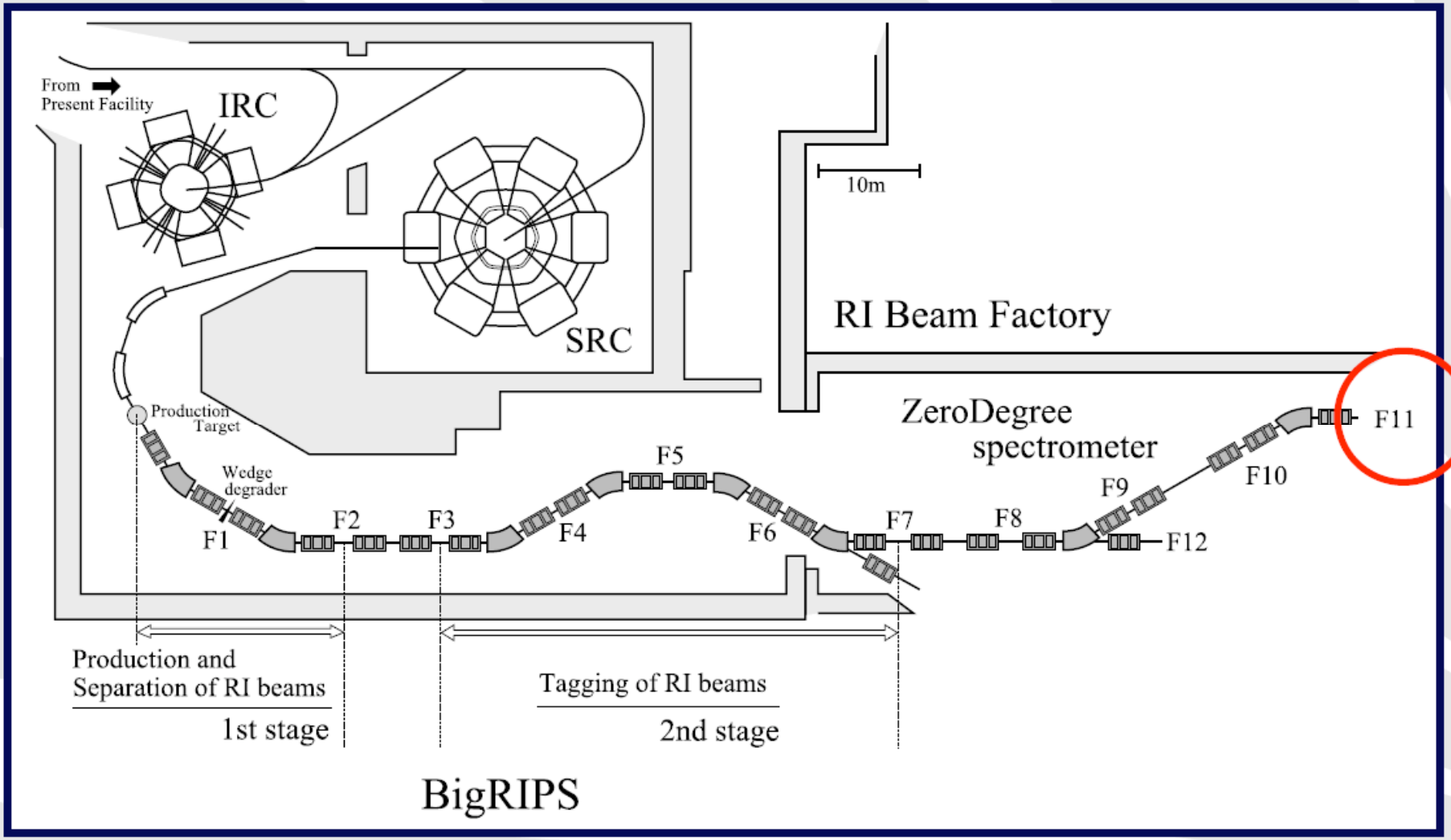
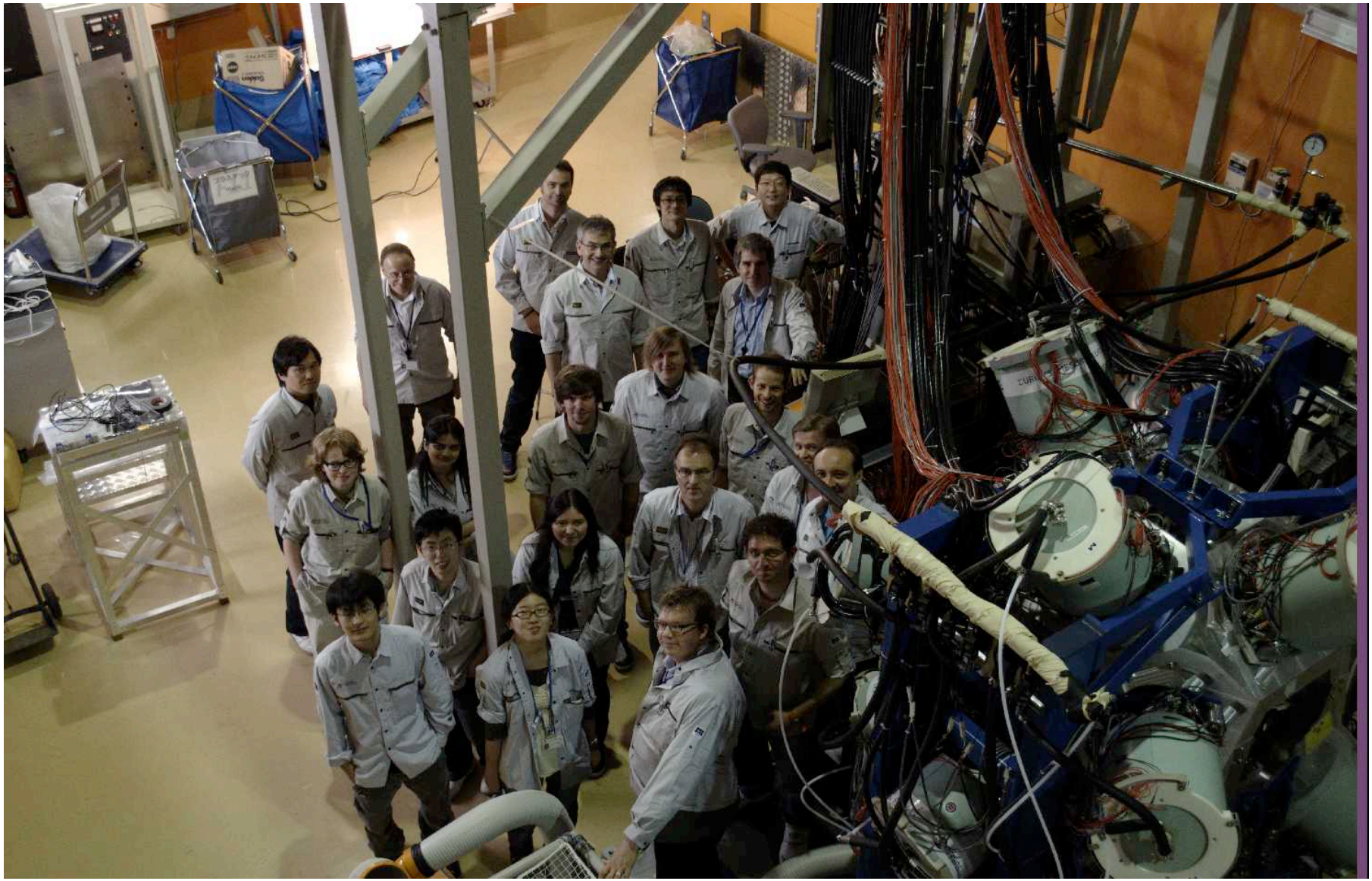
[48] Beihang University, Beijing, China
[49] Justus-Liebig-University, Giessen, Germany
[50] University of Notre Dame, USA
[51] CEA Saclay, France

# Origin of Collaboration Members




e-RI scattering with SCRIT
18GHzECRIS
RILACII
28GHzECRIS
CSM
RILAC
BF1
ZDS
SAMURAI
(2012 ~)
AVF
RRC
BF2
SRC
fRC
Rare RI ring
(2013 ~)
IRC
BigRIPS
SHARAQ
0
50 m


From
Present Facility
IRC
SRC
10m
RI Beam Factory
Production
Target
Wedge
degrader
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11
F12
ZeroDegree
spectrometer
Production and
Separation of RI beams
1st stage
Tagging of RI beams
2nd stage
BigRIPS

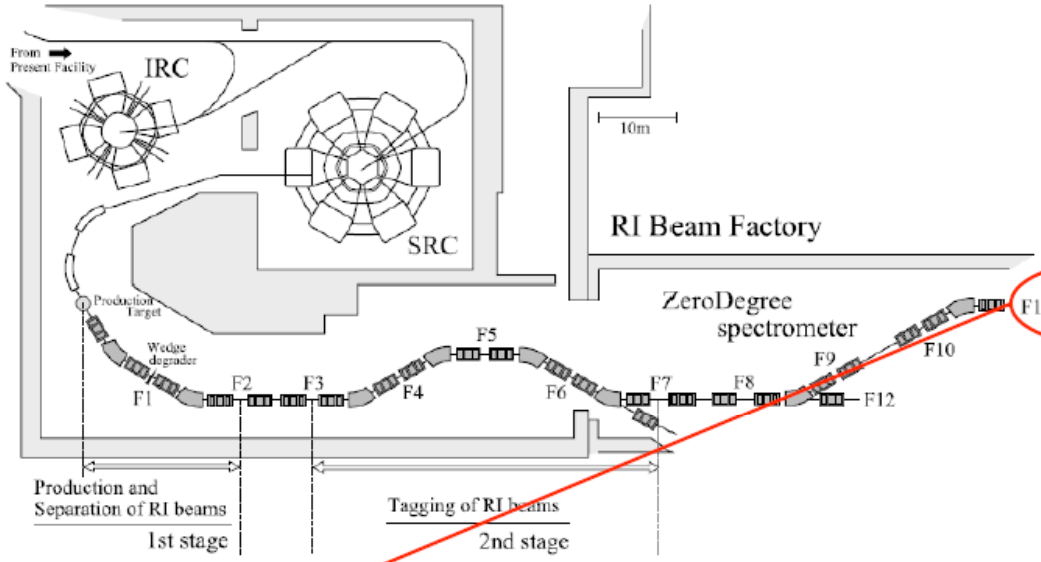


# Proposals accepted at first EURICA PAC

- Exploring the subshell closure at N=34 via beta decay
- Decay Spectroscopy in the vicinity of $^{78}$Ni
- Neutron monopole drift towards to $^{78}$Ni investigated by decay spectroscopy
- Decay spectroscopy of neutron-rich Zr and Mo isotopes
- Decay spectroscopy study of very neutron-rich nuclei Nb—Ag including the r-process waiting point $^{128}Pd_{82}$/Search for long-lived isomers in neutron-rich Cd, Ag, and Pd isotopes
- Study of the isomeric and β-decays of $^{132}$Cd and $^{136,138}$Sn
- Shape evolution in neutron-rich A~140 nuclei beyond the doubly-magic nucleus $^{132}$Sn
- Search for K-Isomers in Neutron-Rich Z ≈ 60 Isotopes
- $^{100}$Sn
- Study of isomer and proton decays in N<Z nuclei below $^{100}$Sn
- Comparison of Tz=-2 beta decays with their mirror process on Tz=2 nuclei and search for isospin suppressed gamma and proton transitions
- Study of isospin symmetry and isoscalar pn-pairing beyond the $f_{7/2}$ shell.
- Search for two-proton radioactivity of $^{59}$Ge, $^{63}$Se, and $^{67}$Kr

EURICA installed at focal plane of Big RIPS separator.

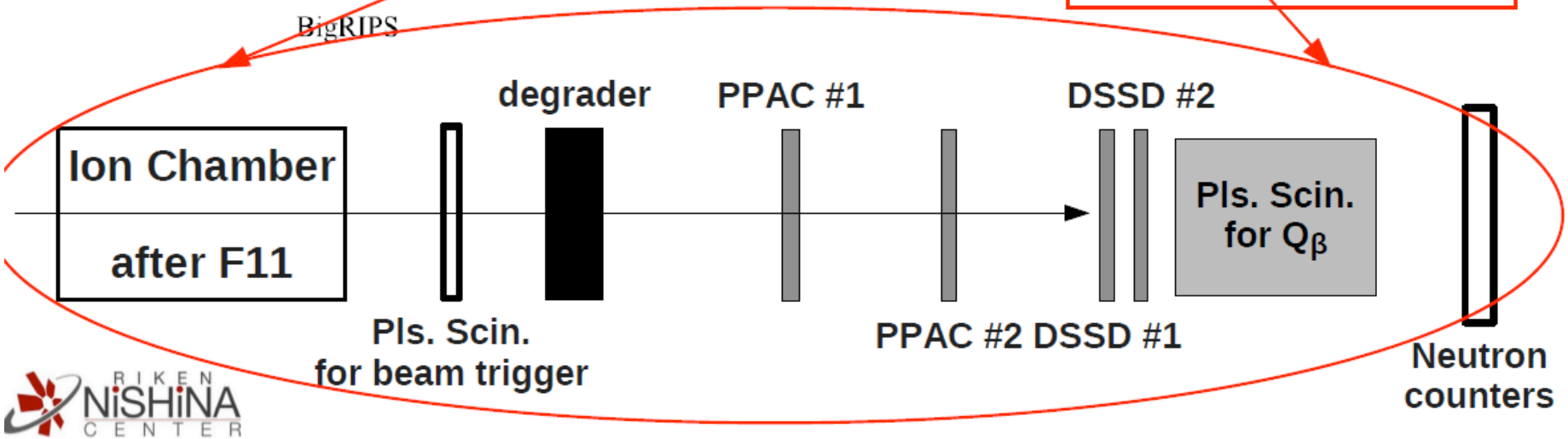
# Scheme of Setup for DSSD




**Primary beam + target**
$^{18}O + {}^{9}Be$

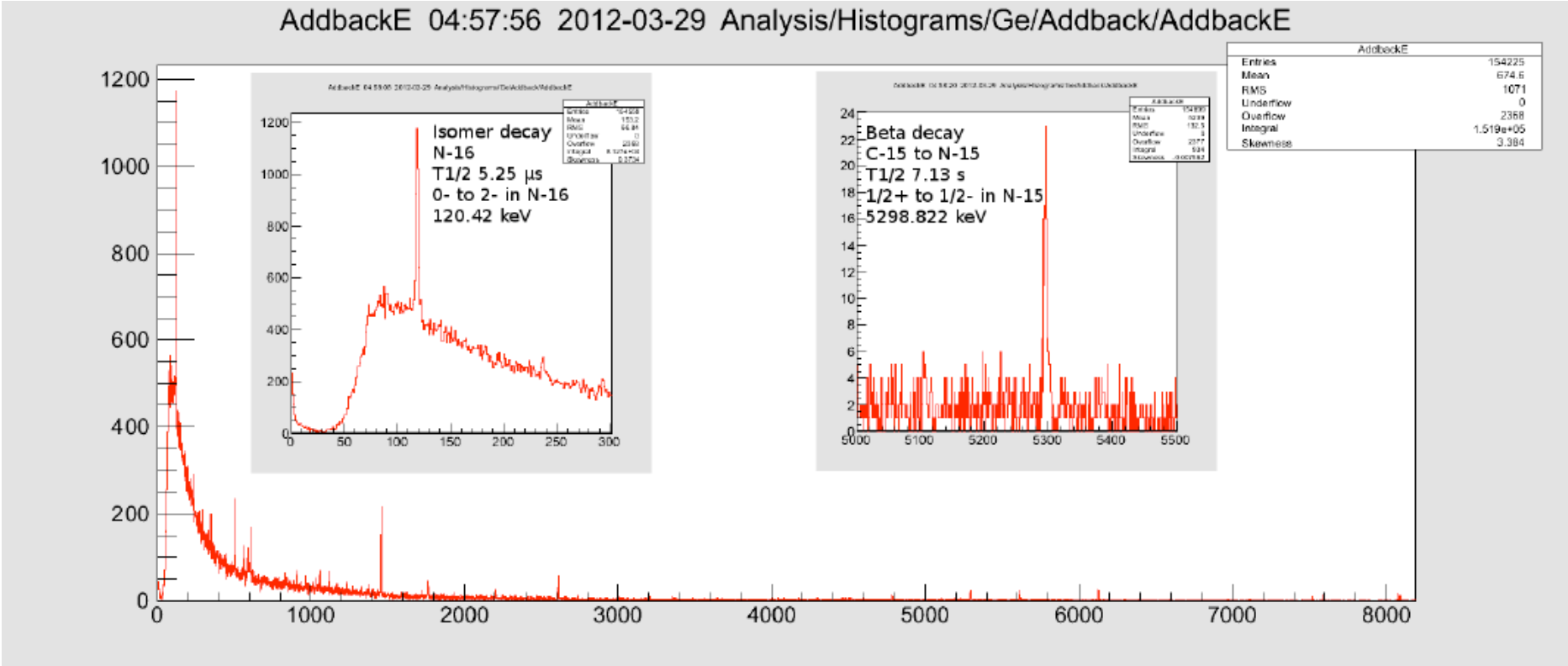
**Three settings:**
1: $^{16}N + {}^{15}C$ (~ 1 day)
2: $^{12}B$ (~ 1 day)
3: $^{17}B$ (~ 2 day)

**PID for secondary beam @ ZeroDegree**
**Bρ-TOF-dE**

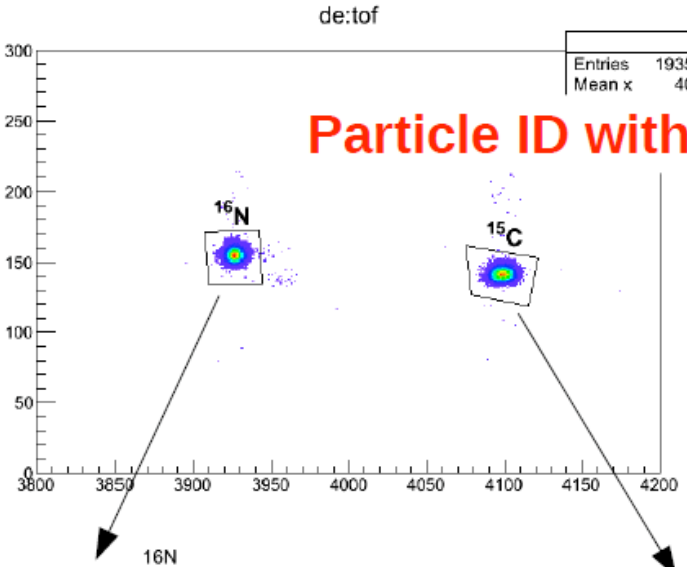


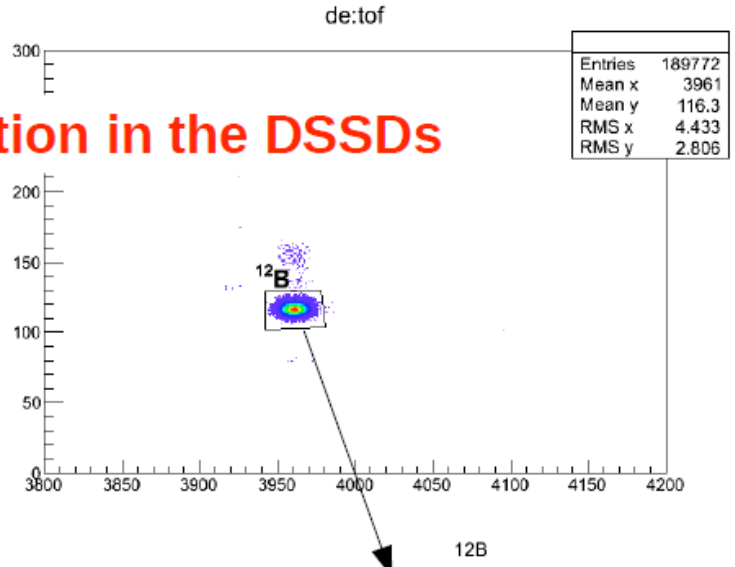

RIKEN NiSHiNA CENTER

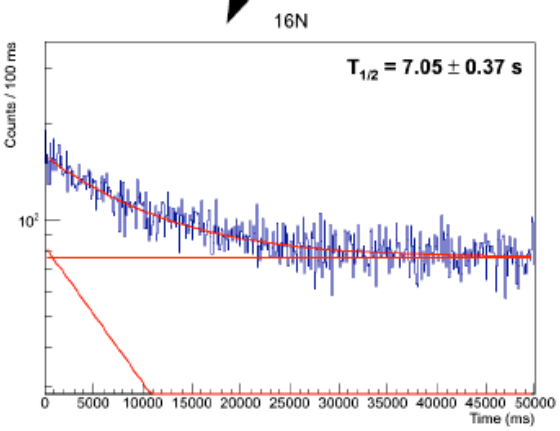
- March 29, two days
- BigRIPS setting using $^{18}O$ beam
- β-decay of $^{16}N$ to $^{16}O$
- β-decay of $^{15}C$ to $^{15}N$
- Isomer decay of $^{16}N$

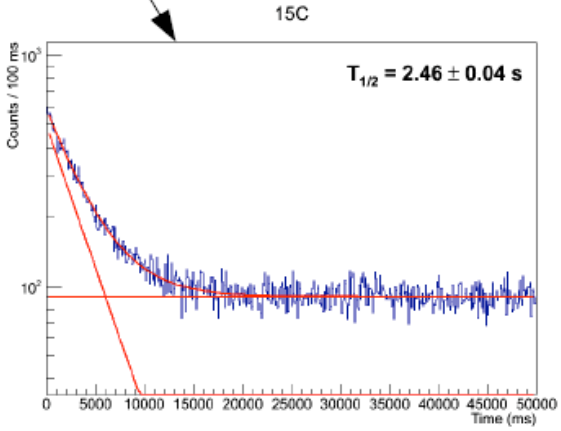


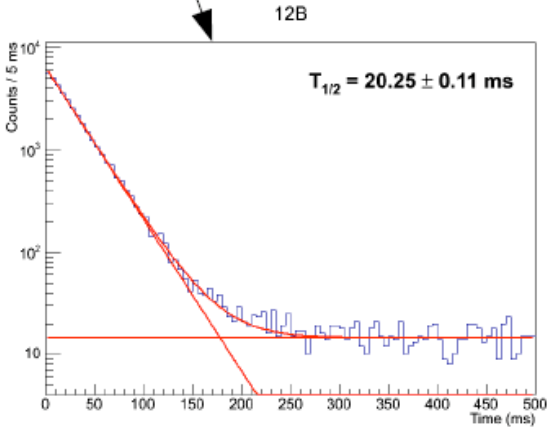
# Particle ID with implantation in the DSSDs



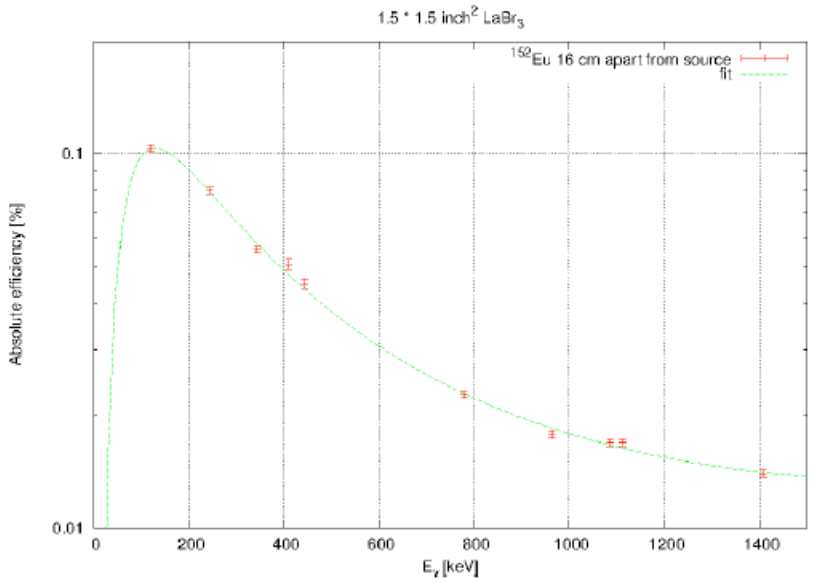




# Decay curve (in ms) for different implanted nuclide

# Complementary $LaBr_3$ array?

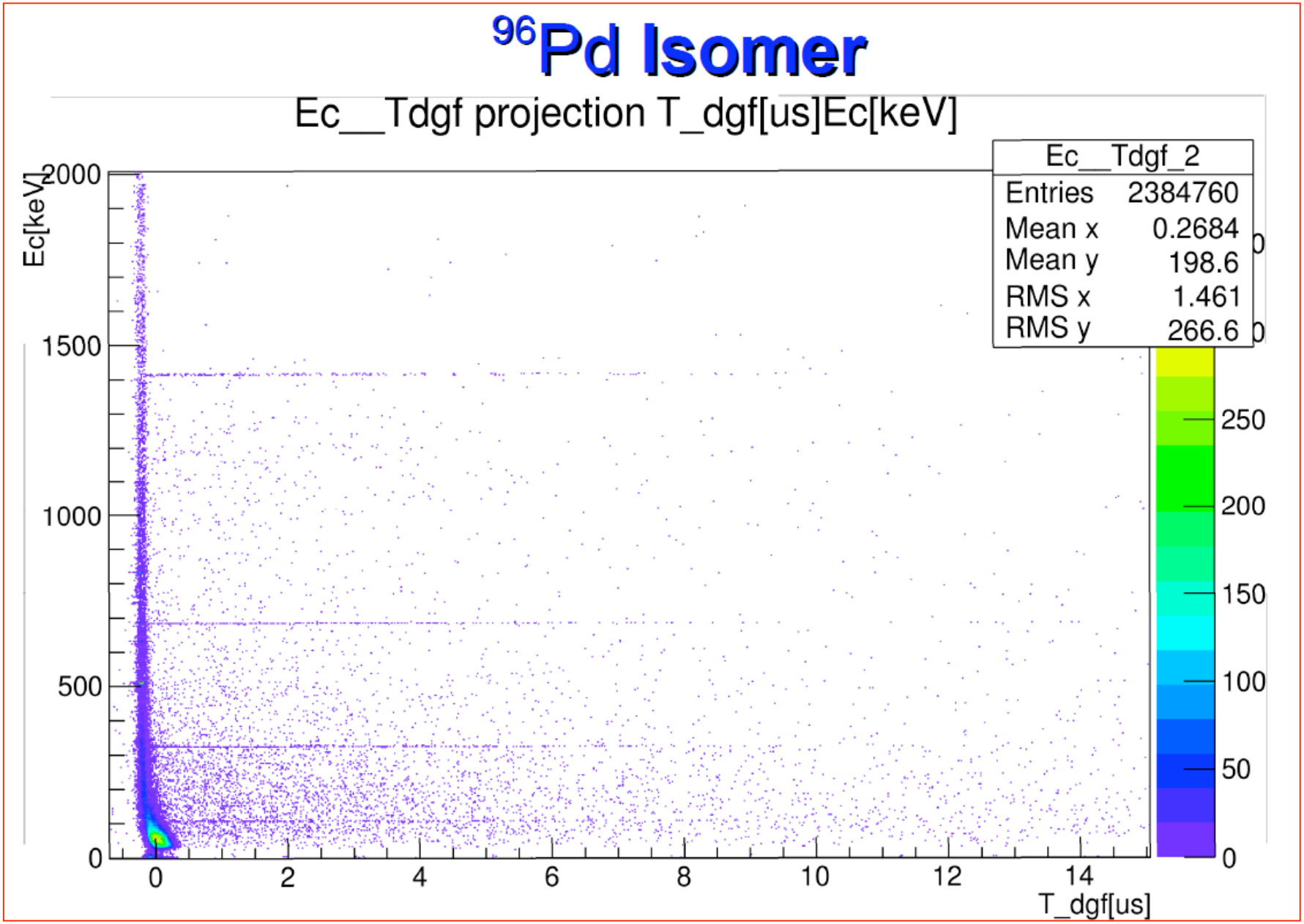



- Possible complementary array for fast timing
- 21 LaBr3 available from the UK?
- Three clusters of seven crystals
- To be continnued...

# ‘A’ grade approved EURICA experiments

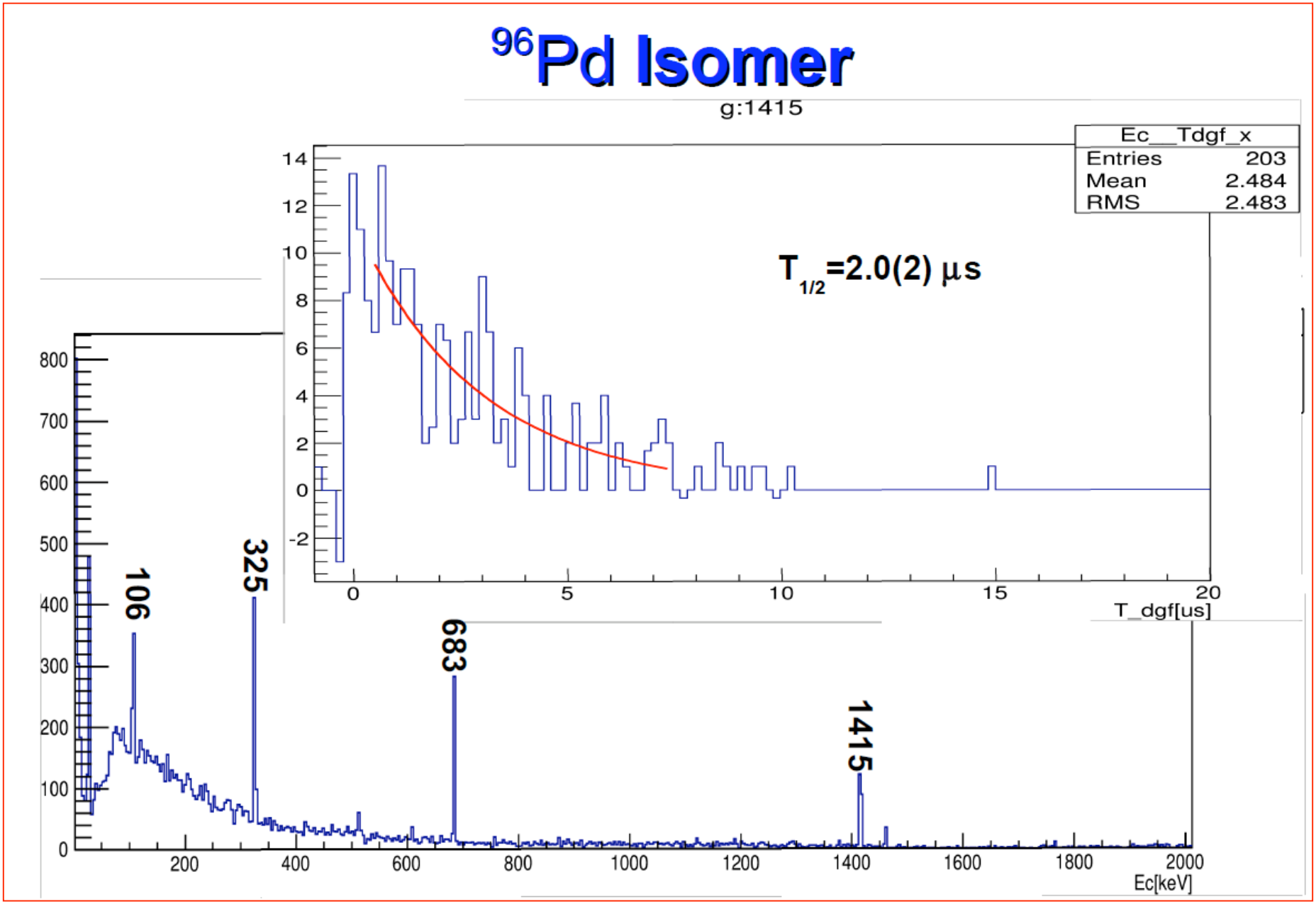
| Spokesperson/e-mail | Title | Primary | Days Approved |
|---|---|---|---|
| Grade A | | | |
| Jose Javier Valiente-Dobon (LNL) valiente@lnl.infn.it David Steppenbeck | Exploring the subshell closure at N=34 via beta decay | 238U (86Kr) | 7 |
| Shunji Nishimura (RIKEN) nishimu@riken.jp | Decay Spectroscopy in the vicinity of $^{78}$Ni | 238U | 7.5? |
| Megumi Niikura (IPN Orsay) niikura@ipno.in2p3.fr | Neutron monopole drift towards to $^{78}$Ni investigated by decay spectroscopy | 238U | 11 |
| Toshiyuki Sumikama (Tokyo Science) sumikama@ph.noda.tus.ac.jp | Decay spectroscopy of neutron-rich Zr and Mo isotopes | 238U | 10.5 |
| Giuseppe Lorusso (RIKEN) lorusso@ribf.riken.jp Hiroshi Watanabe (RIKEN) hiroshi@ribf.riken.jp | Decay spectroscopy study of very neutron-rich nuclei Nb—Ag including the r-process waiting point $^{128}$Pd$_{82}$/Search for long-lived isomers in neutron-rich Cd, Ag, and Pd isotopes | 238U | 13 |
| Gary Simpson (Grenoble) simpson@lpsc.in2p3.fr Andres Gadea (Valencia) gadea@ific.uv.es Andrea Jungclaus (Madrid) andrea.jungclaus@iem.cfmac.csic.es | Study of the isomeric and ß-decays of $^{132}$Cd and $^{136,138}$Sn | 238U | 6 |
| Atsuko Odahara (Osaka) odahara@phys.sci.osaka-u.ac.jp Radomira Lozeva (IPHC, CNRS/IN2P3) radomira.lozeva@iphc.cnrs.fr Changbum Moon (Hoseo) | Shape evolution in neutron-rich A~140 nuclei beyond the doubly-magic nucleus 132Sn | 238U | 5 |
| Eiji Ideguchi (CNS, Tokyo) ideguchi@cns.s.u-tokyo.ac.jp Gary Simpson | Search for K-Isomers in Neutron-Rich Z ≈ 60 Isotopes | 238U | 7 |
| Marek Lewitowicz (GANIL) lewitowicz@ganil.fr | 100Sn | 124Xe | 9 or 10? |
| Plamen Boutachkov (Darmstadt) P.Boutachkov@gsi.de Robert Wadsworth (York) rw10@npg.york.ac.uk A. Blazhev (Cologne) Z. Liu (Edinburgh) | Study of isomer and proton decays in N<Z nuclei below $^{100}$Sn | 124Xe | 7 |
| Berta Rubio (Valencia) Berta.Rubio@ific.uv.es Yoshitaka Fujita (Osaka) fujita@rcnp.osaka-u.ac.jp William Gelletly (Surrey) W.Gelletly@surrey.ac.uk | Comparison of Tz=-2 beta decays with their mirror process on Tz=2 nuclei and search for isospin suppressed gamma and proton transitions | 78Kr | 5 |
| A. Algora(Valencia), Alejandro.Algora@ific.uv.es G de Angelis(Legnaro), Giacomo.DeAngelis@lnl.infn.it F. Recchia(Padova) francesco.recchia@pd.infn.it B. Rubio(Valencia) Berta.Rubio@ific.uv.es | Study of isospin symmetry and isoscalar pn-pairing beyond the $f_{7/2}$ shell. | 78Kr | 5 |
| Bertram Blank (CEN Bordeaux-Gradignan) blank@cenbg.in2p3.fr | Search for two-proton radioactivity of $^{59}$Ge, $^{63}$Se, and $^{67}$Kr | 78Kr | 6 |

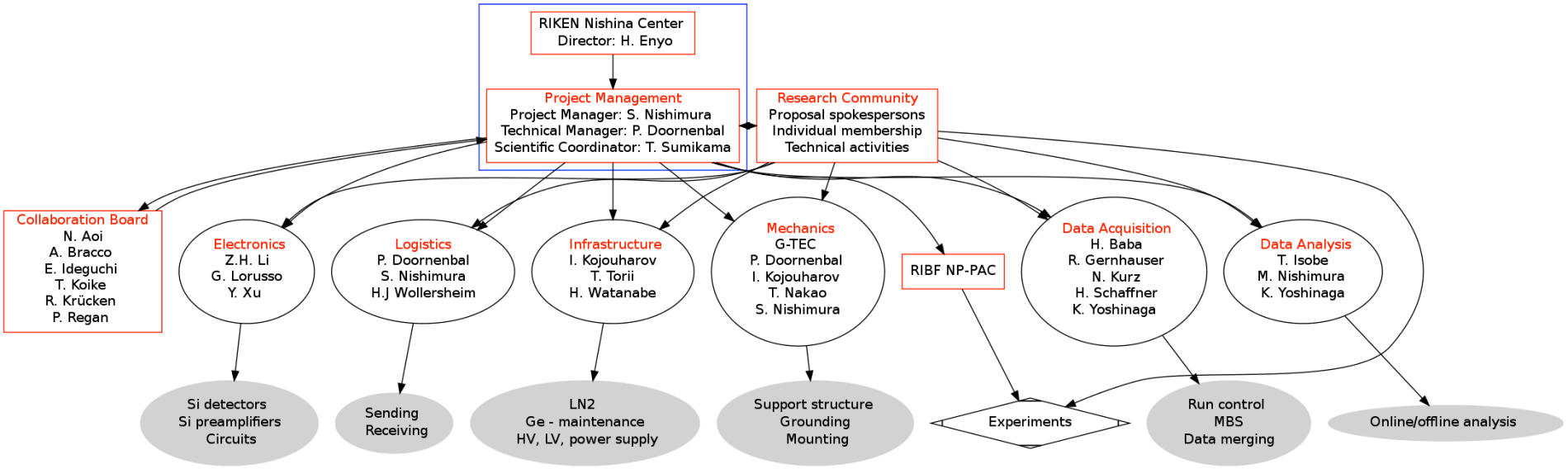
# $^{96}$Pd Isomer



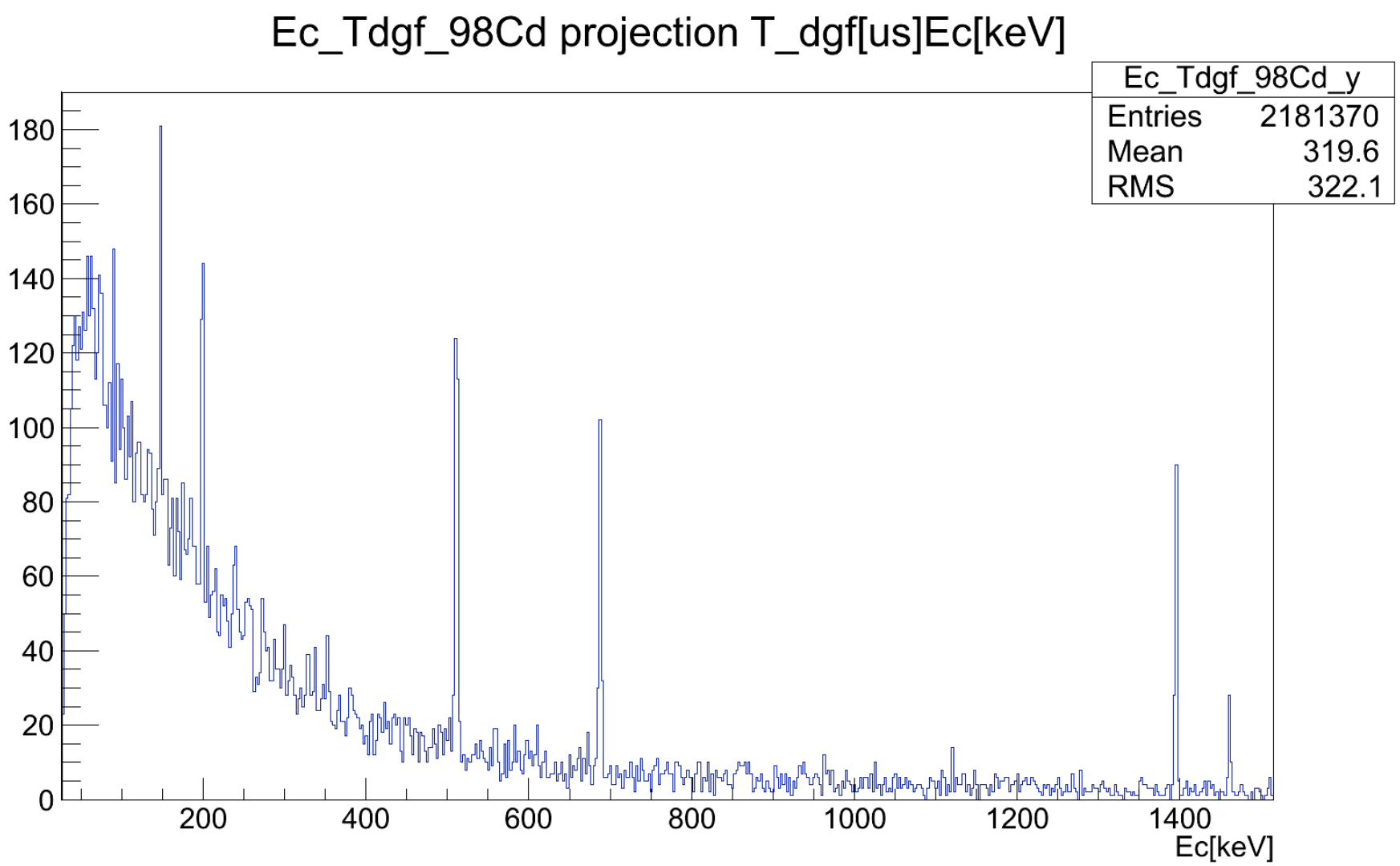

P. Boutachkov et al.,

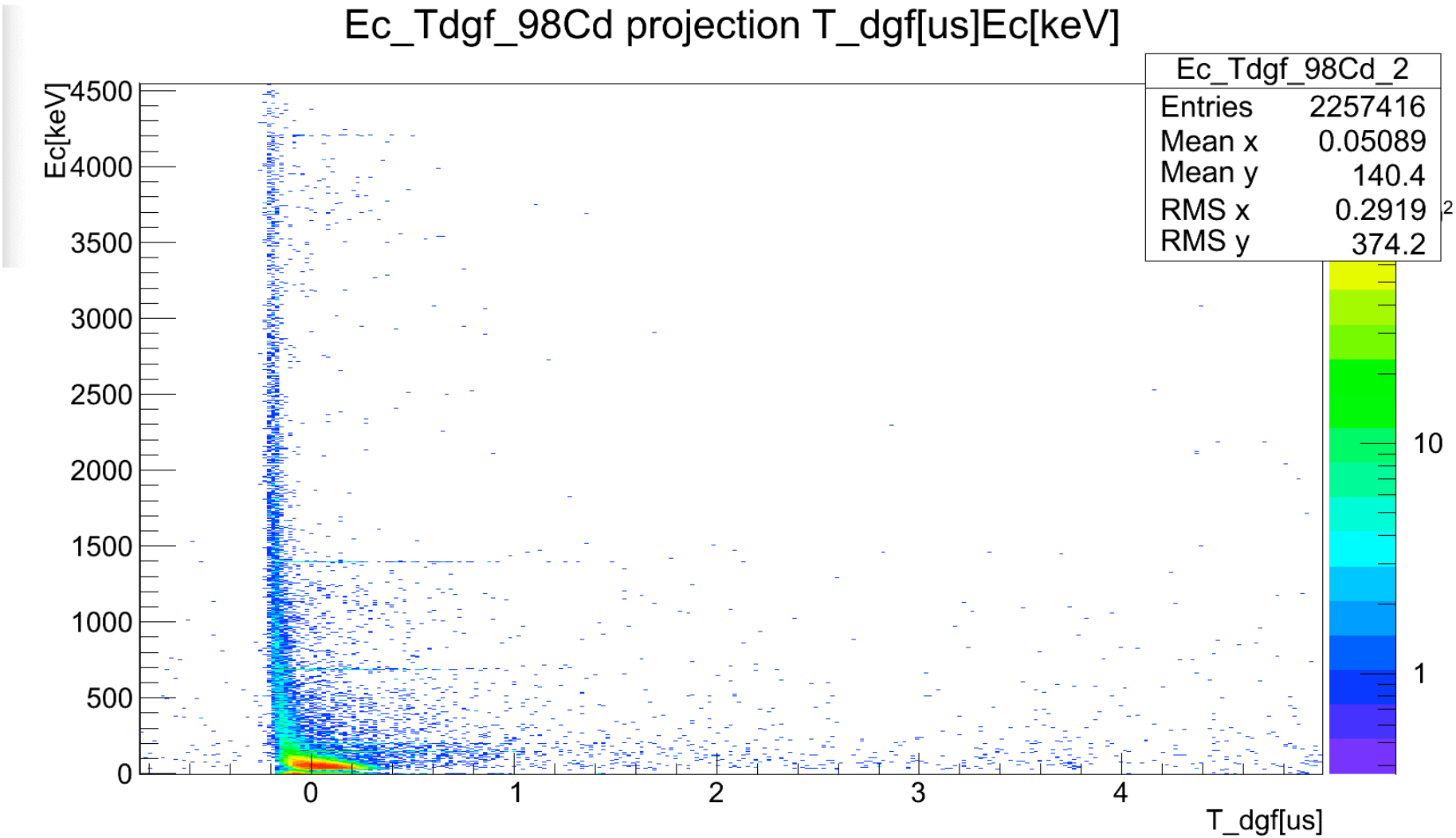
P. Boutachkov et al.,






EURICA Organigram
drawn by PM and TM


Ec_Tdgf_98Cd projection T_dgf[us]Ec[keV]
Ec_Tdgf_98Cd_y
Entries 2181370
Mean 319.6
RMS 322.1
180
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
Ec[keV]


Ec_Tdgf_98Cd projection T_dgf[us]Ec[keV]
Ec_Tdgf_98Cd_2
Entries 2257416
Mean x 0.05089
Mean y 140.4
RMS x 0.2919
RMS y 374.2
Ec[keV]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
T_dgf[us]
10
1

# Previously approved and future experiments discussed at workshop.

| Experiment | Nuclei Aimed for | Spokesperson | Primary Beam | Approved Remaining |
|---|---|---|---|---|
| NP0912-RIBF35 | $^{41}$Si | Z. Li | $^{48}$Ca | 5/5 |
| | $^{64,66}$Se | B. Rubio, Y. Fujita, W. Gelletly | $^{78}$Kr | –/– |
| | $^{55}$Sc | J. Valiente Dobon, G. de Angelis | $^{86}$Kr | –/– |
| NP0702-RIBF09 | $^{100}$Sn | M. Lewitowicz, R. Krücken, S. Nishimura | $^{124}$Xe | 10/10 |
| NP0802-RIBF60 | $^{127}$Ag, $^{129}$Cd | H. Watanabe | $^{136}$Xe | 6/6 |
| | $^{70,72}$Fe | G. Benzoni, H. Watanabe | $^{238}$U | –/– |
| NP0702-RIBF10 | $^{78}$Ni | S. Nishimura | $^{238}$U | 7.5/7.5 |
| | $^{81}$Cu | M. Niikura | $^{238}$U | –/– |
| | n-rich Ge, Se, Kr | A. Odahara | $^{238}$U | –/– |
| | $^{92,94}$Se | R. Krücken | $^{238}$U | –/– |
| NP1012-RIBF53 | $^{110,112}$Mo | T. Bäck, E. Ideguchi | $^{238}$U | ?/? |
| NP0702-RIBF26 | $^{108,110}$Zr | T. Sumikama | $^{238}$U | 4/1 |
| NP1012-RIBF62 | $^{128}$Pd | G. Lorusso | $^{238}$U | ?/? |
| NP0811-RIBF69 | $^{136,138}$Sn, $^{132,134}$Cd | A. Gadea, A. Jungclaus, G. Simpson | $^{238}$U | 7/7 |
| | $^{137}$Sb, $^{138,139}$Te | R. Lozeva | $^{238}$U | –/– |
| | n-rich Ba and Xe | A. Odahara | $^{238}$U | –/– |
| | $^{170}$Dy | H. Watanabe | $^{238}$U | –/– |