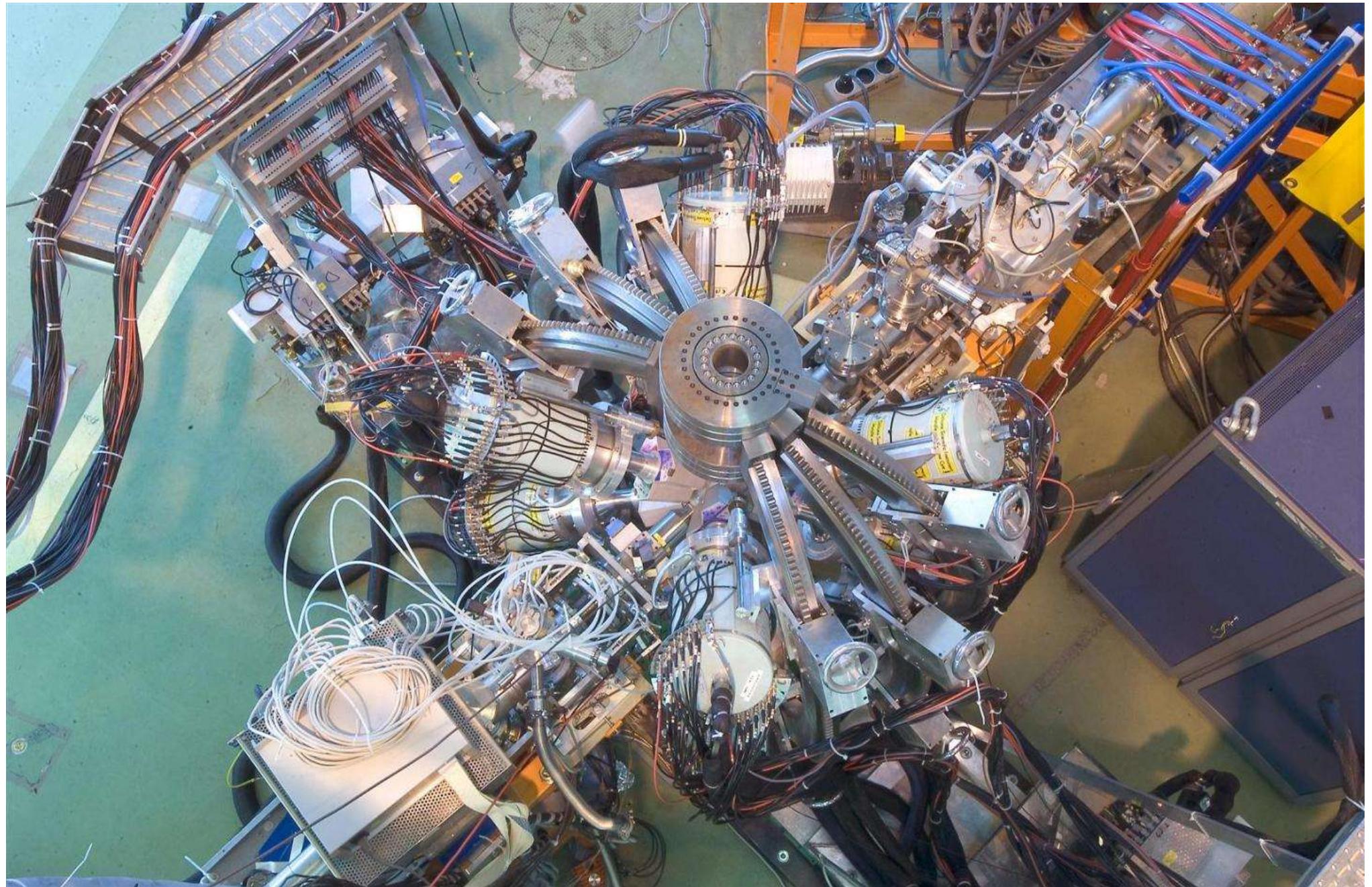


MINIBALL@ISOLDE, CERN



MINIBALL

Status and perspectives of the nuclear structure experiments at ISOLDE

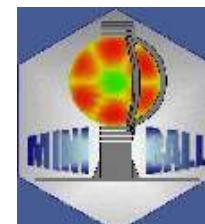
Peter Reiter

IKP, University of Cologne

- MINIBALL @ REX-ISOLDE
- Physics case
- High Intensity and Energy ISOLDE - HIE ISOLDE
- First results
- Summary

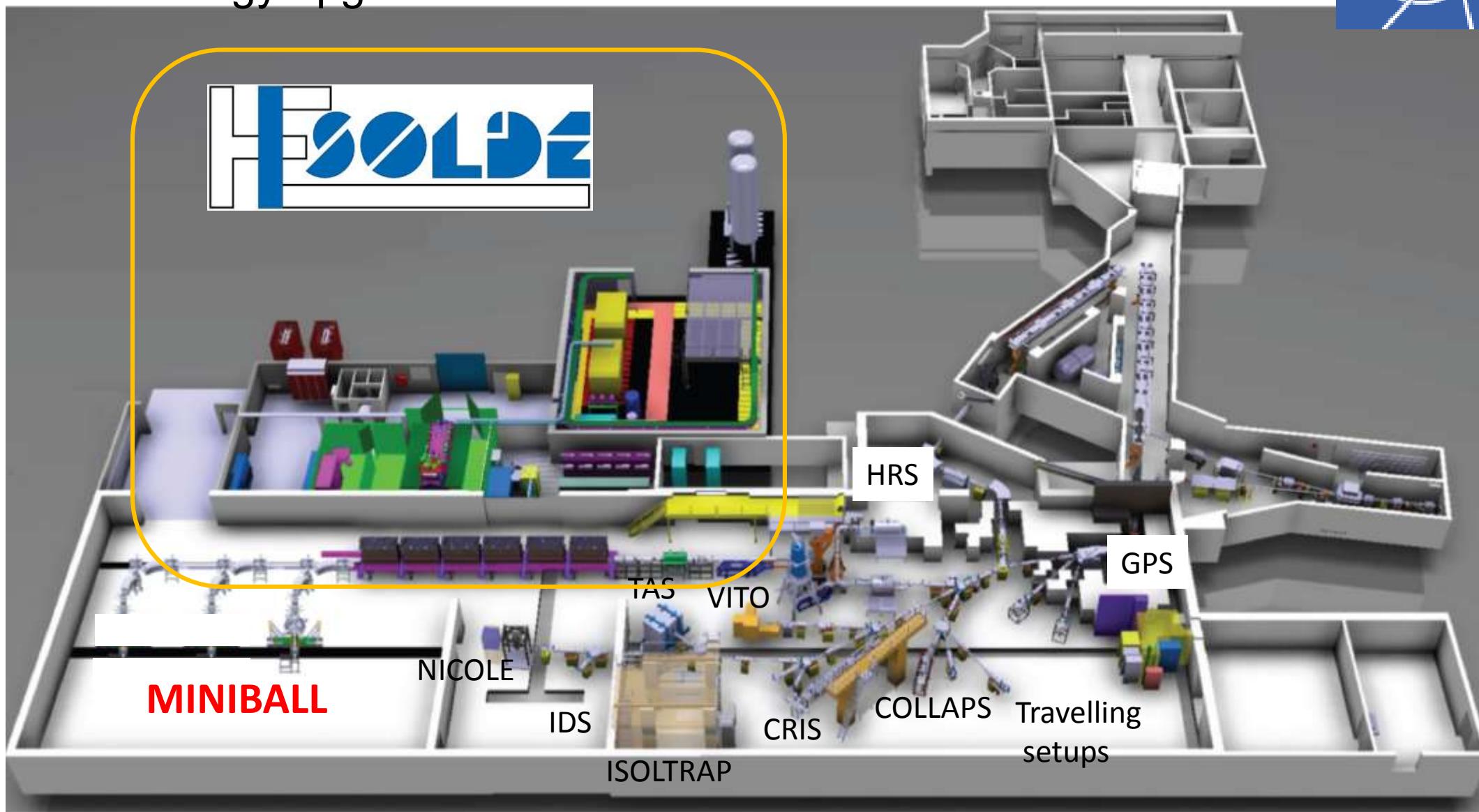


BEFÖRDERT VOM

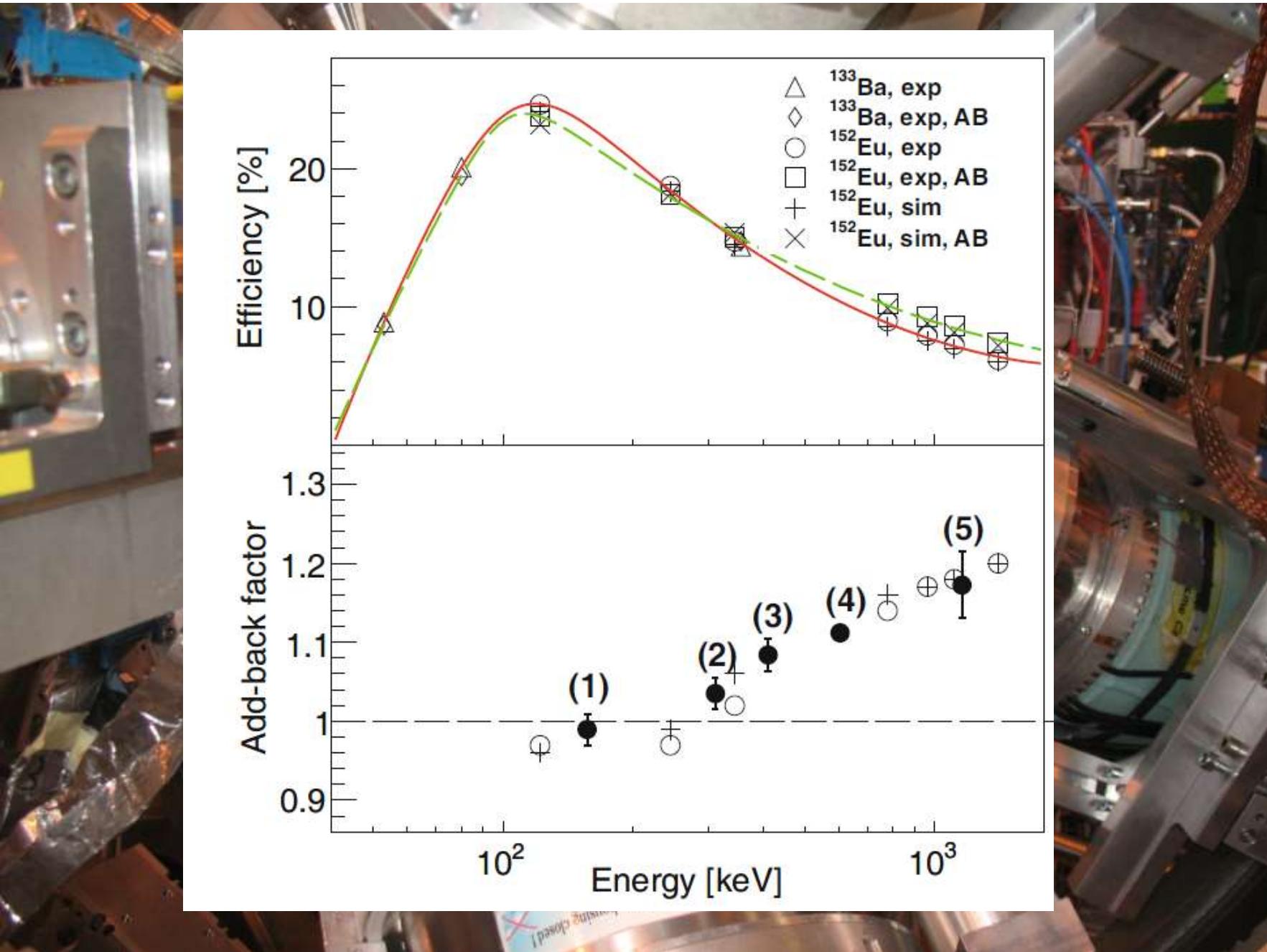


HIE-ISOLDE

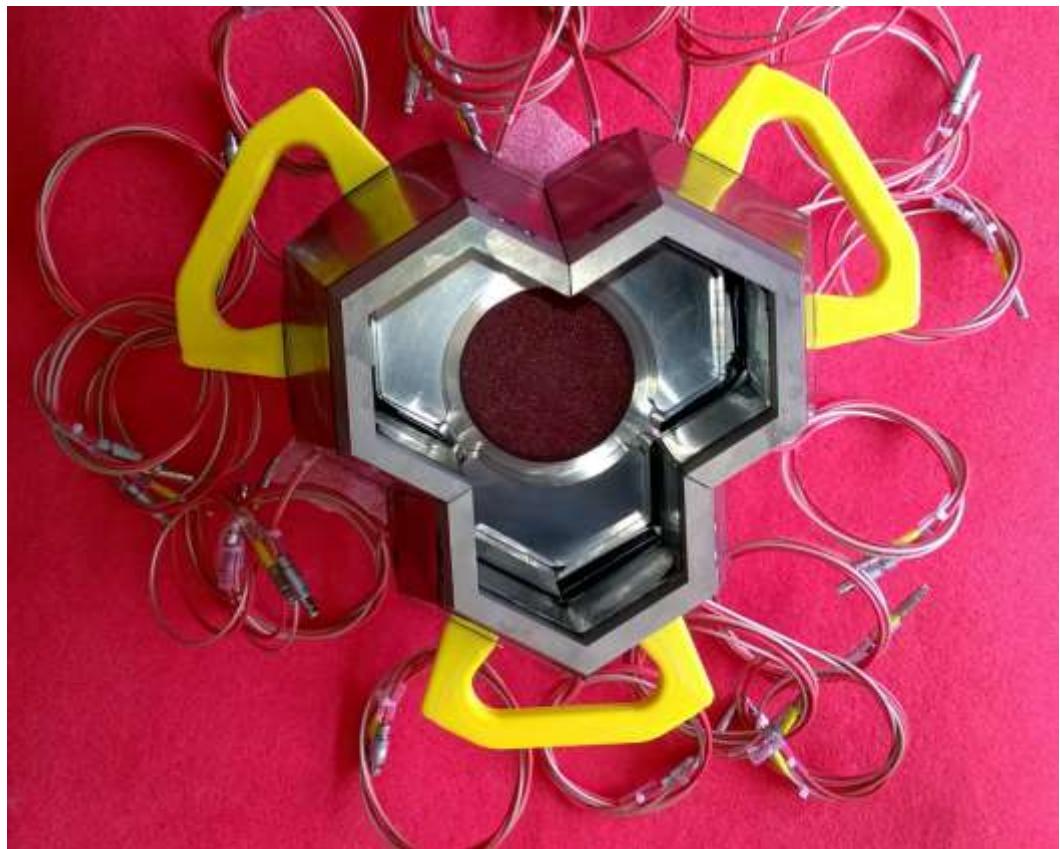
- intensity upgrade
- energy upgrade



MINIBALL spectrometer



MINIBALL Anti-Compton shield



Particle detector setups

Coulomb excitation setup:

Si detector (DSSSD) for particle detection

- 16 rings (front), 96 strips (back)
- angle coverage: $\theta_{\text{lab}} = 16\text{-}55^\circ$
- $\Delta E\text{-}E$ measurement



Transfer reaction setup:

Si detector array for

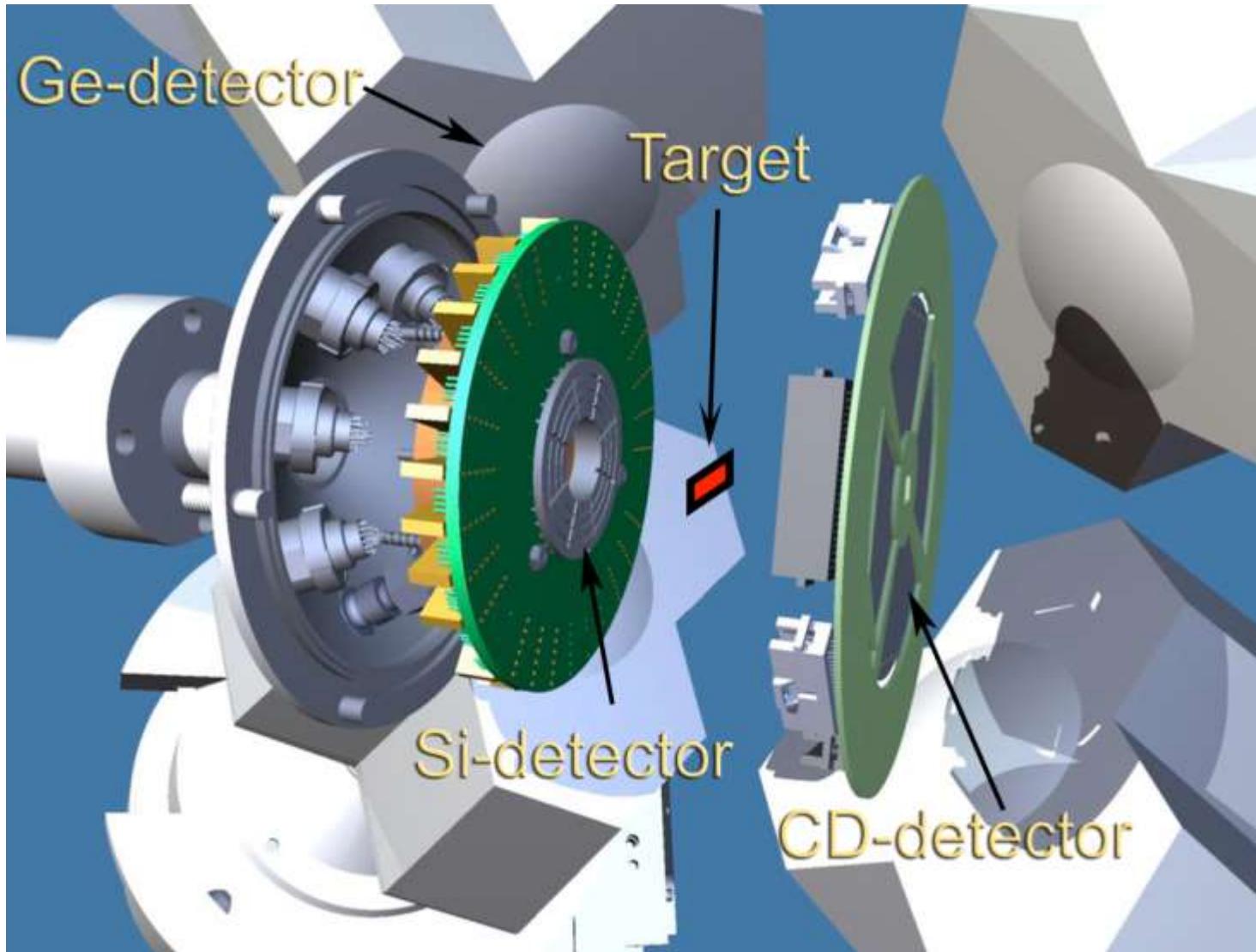
Transfer experiments at REX-ISOLDE
T-REX

- large solid angle (58% of 4π)
- position sensitive
- PID ($\Delta E\text{-}E$): p, d, t, a,



Conversion electron spectrometer

SPEDE - SPectrometer for Electron DEtection



J. Pakarinen, Jyväskylä

MINIBALL physics case

Shell Model Physics with MINIBALL@REX-ISOLDE

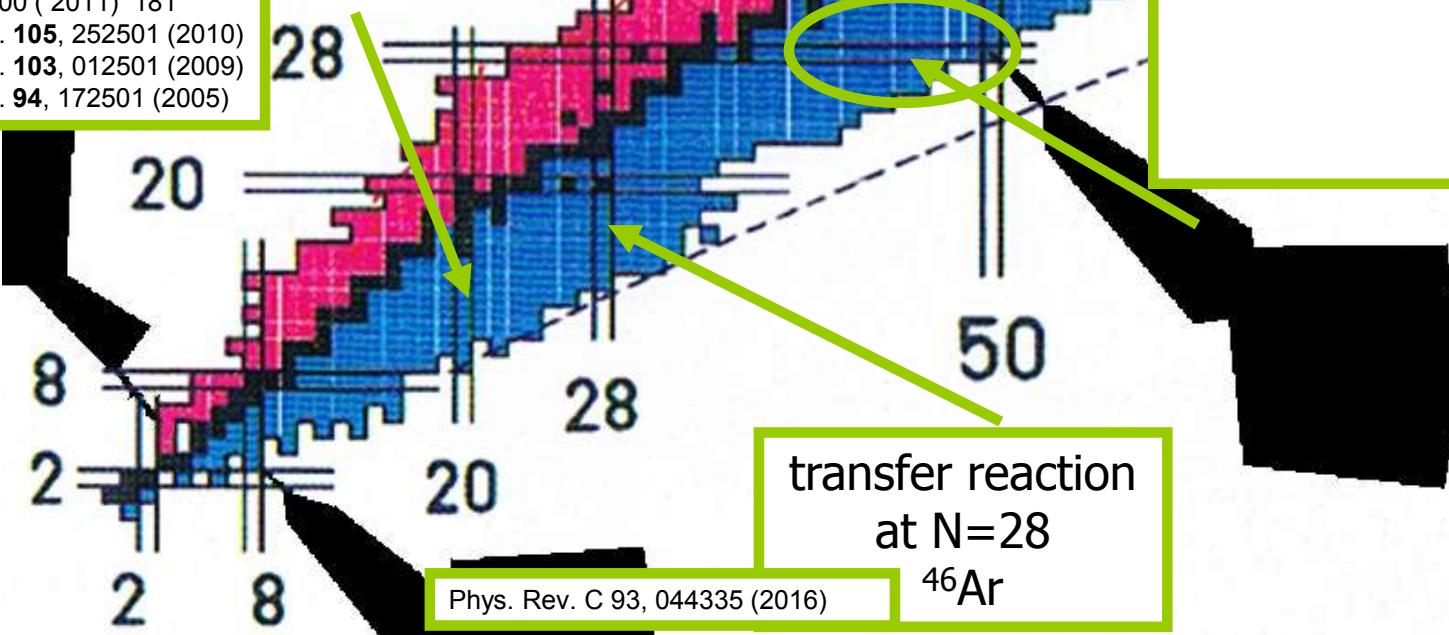
"Island of inversion" N=20
Coulomb excitation & transfer reactions

26,30,31,32Mg
28,29,30Na

Phys. Rev. C 93, 044335 (2016)
Phys. Rev. C 91, 014311 (2015)
Phys. Rev. C 89, 024309 (2014)
Phys. Lett. B, 700 (2011) 181
Phys. Rev. Lett. 105, 252501 (2010)
Phys. Rev. Lett. 103, 012501 (2009)
Phys. Rev. Lett. 94, 172501 (2005)

Towards the doubly magic ^{78}Ni
with Coulomb excitation and nucleon
transfer reactions around ^{68}Ni

72,74,76,78,79,80Zn
67,68,69,70,71,73Cu
66,67,68Ni
61,62Mn, 61,62Fe



Eur. Phys. J. A 51: 136 (2015)
Phys. Rev. C 91, 054321 (2015)
Phys. Lett. B 740, 298 (2015)
Phys. Lett. B 736, 533 (2014)
Phys. Rev. C 89, 054316 (2014)
Phys. Rev. C 84, 064323 (2011)
Phys. Rev. C 82, 064309 (2010)
Phys. Rev. C. 79, 014309 (2009)
Phys. Rev. Lett. 100, 112502 (2008)
Phys. Rev. C. 78, 047301 (2008)
Phys. Rev. Lett. 99, 142501 (2007)
Phys. Rev. Lett. 98, 122701 (2007)

MINIBALL physics case

Shell Model Physics with MINIBALL@REX-ISOLDE

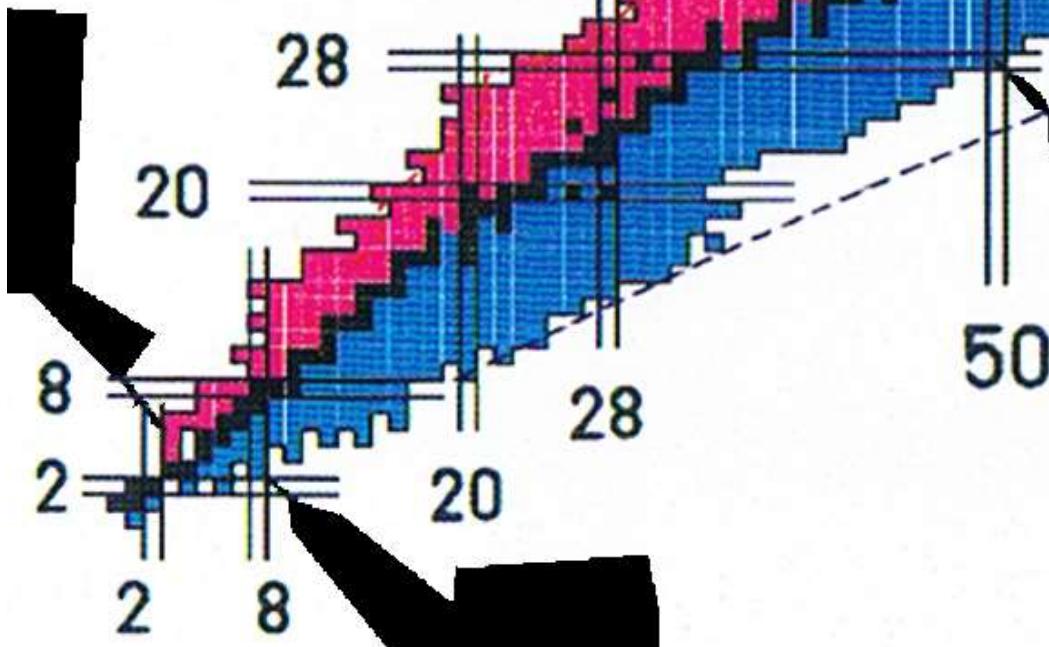
Towards the doubly magic ^{100}Sn

106,107,108,109,110 Sn

107,108 In

100,102,104 Cd

Phys. Rev. C 87, 017301 (2013)
Eur. Phys. J. A 48: 105 (2012)
Eur. Phys. J. A 44 (2010) 355
Phys. Rev. C 86, 031302 (2012)
Phys. Rev. C 80, 054302 (2009)
Phys. Rev. Lett. 101, 012502 (2008)
Phys. Rev. Lett. 98, 172501 (2007)



B(E2) measurement around ^{132}Sn

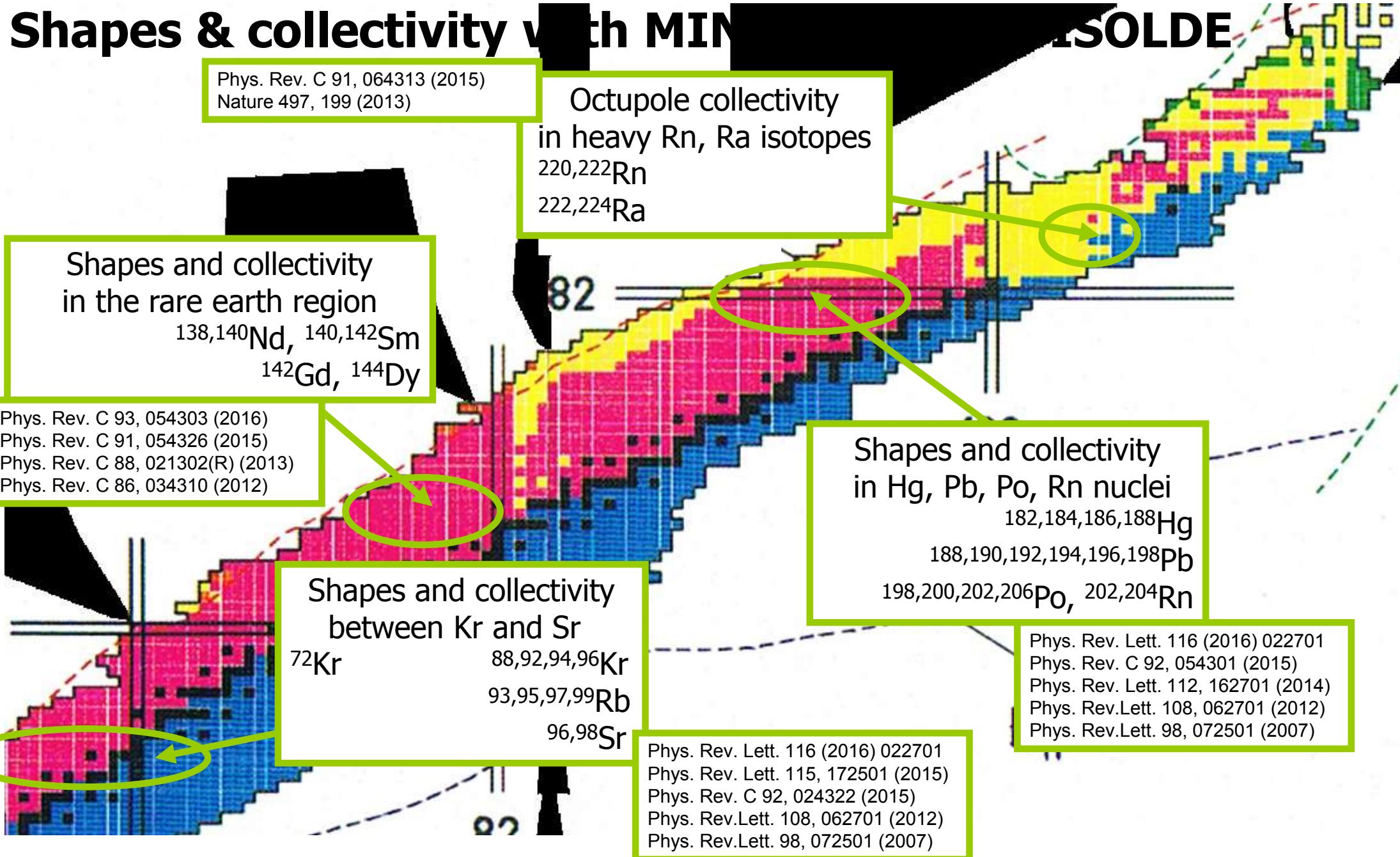
122,124,128 Cd

8,140,142,144 Xe

140,142,148 Ba

Phys. Rev. C 89, 014313 (2014)
Phys. Rev. C 86, 034310 (2012)

MINIBALL physics case



REX/HIE-ISOLDE post-accelerator:

*Jose Alberto Rodriguez for the
HIE-ISOLDE operation team*

The REX normal conducting linac:

- Beam from the REX-EBIS charge breeder with 5 keV/u energy is accelerated to 2.85 MeV/u
- Six normal conducting RF structures with a $f = 101.28$ MHz (9gap at 202.56 MHz) and a 10 % maximum duty cycle
- Transport and delivery of intermediate energies possible

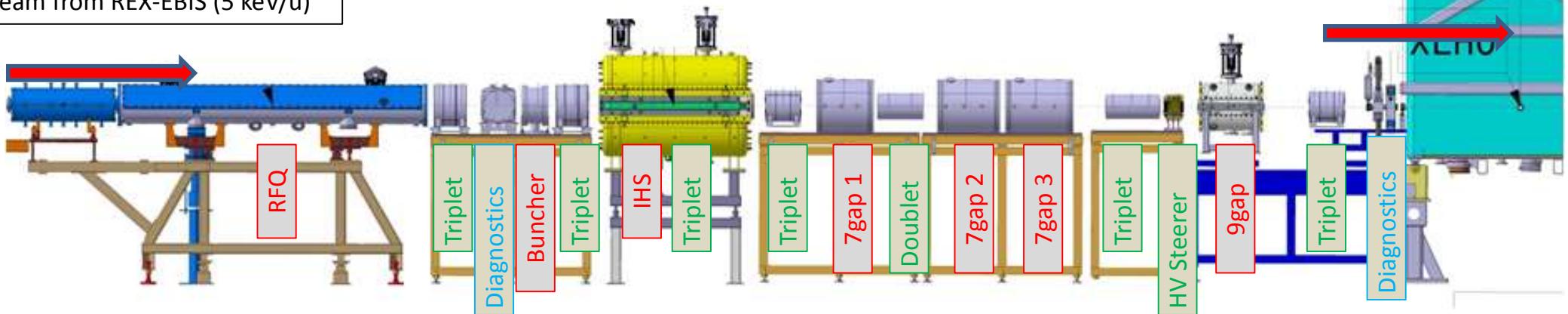
REX RF systems:

RF structure	E_f [MeV/u]	β_f [%]	P [kW] ($A/q = 4.0$)
RFQ	0.3	2.5	29
Buncher	0.3	2.5	1.3
IHS	1.2	5.1	40
7gap1	1.55	5.7	60
7gap2	1.88	6.3	60
7gap3	2.2	6.8	60
9gap	2.85	7.8	71

The REX normal conducting linac:



Beam from REX-EBIS (5 keV/u)



Beam to HIE-ISOLDE
(2.85 MeV/u)

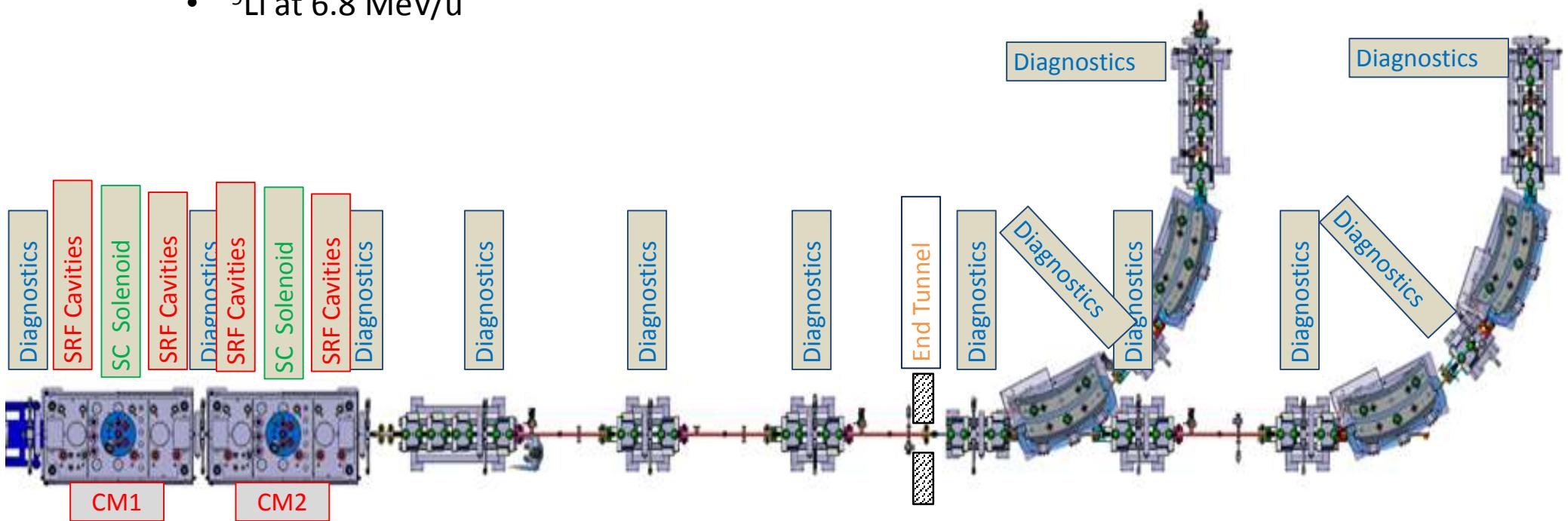
REX/HIE-ISOLDE post-accelerator:

Jose Alberto Rodriguez for the
HIE-ISOLDE operation team

The HIE-ISOLDE super conducting linac and HEBT lines:

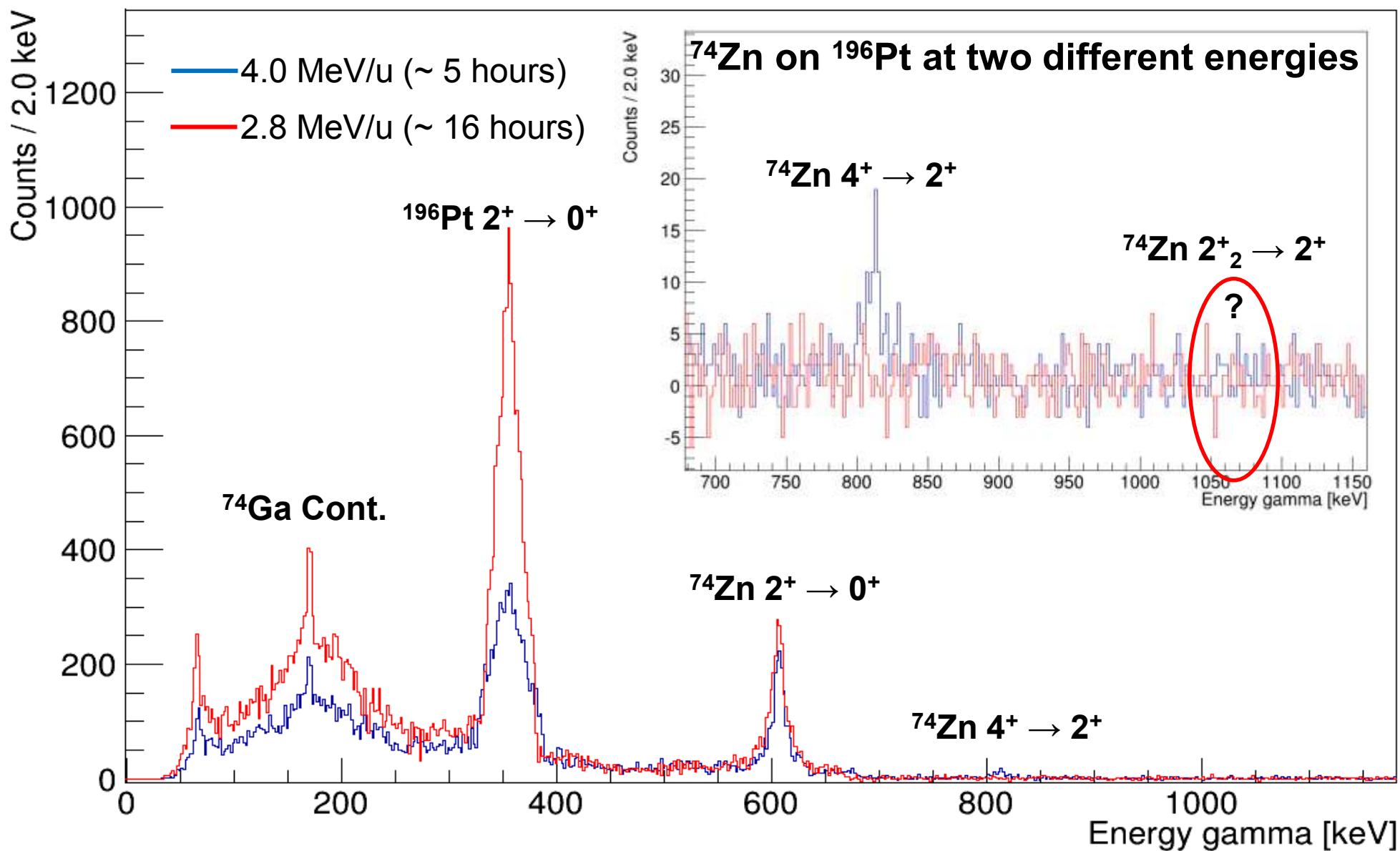
- Project divided into different phases to optimize resources and maximize physics output
- Phase 1B completed in 2016 (two cryomodules and two high energy transfer lines (HEBTs))
- Six experiments delivered to users after machine was commissioned in 2015
 - ^{78}Zn at 4.3 MeV/u
 - ^{110}Sn , ^{142}Xe and ^{66}Ni at 4.5 MeV/u
 - ^{132}Sn at 5.5 MeV/u
 - ^9Li at 6.8 MeV/u

Phases of the HIE-ISOLDE project				
Phase	1A	1B	2A	2B
Completed in:	2015	2016	2017	2018
# cryomodules	1	2	3	4
# HEBT lines	2	2	3	3
$E_{\max} [\text{MeV/u}]$ ($A/q = 2.5$)	5.6	8.6	11.5	14.2
$E_{\max} [\text{MeV/u}]$ ($A/q = 4.33$)	4.4	6.1	7.9	9.6



First Coulex experiment at HIE ISOLDE 10/2015

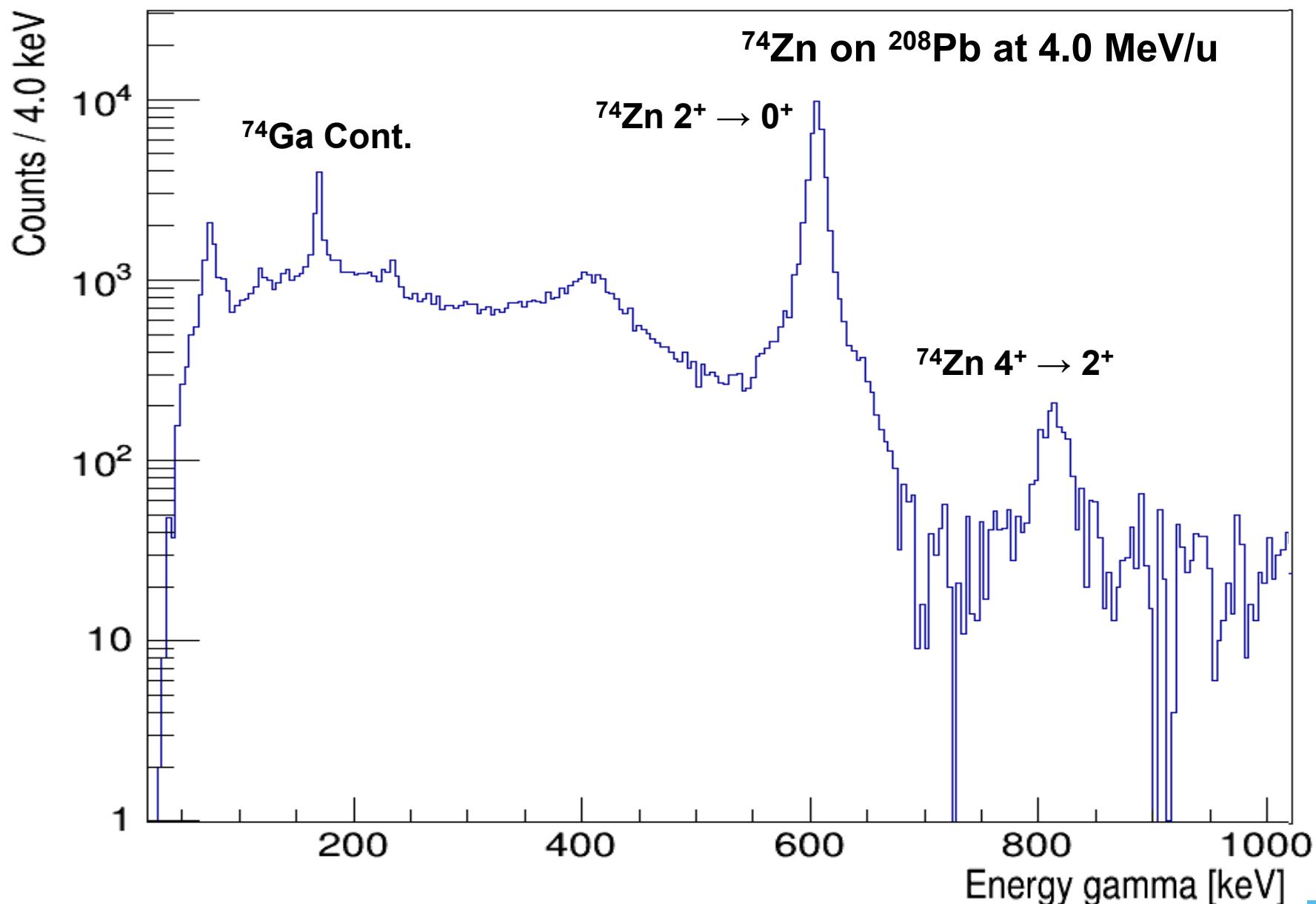
$^{74}\text{Zn}(10^6 \text{ pps}) + ^{196}\text{Pt}$



KU LEUVEN

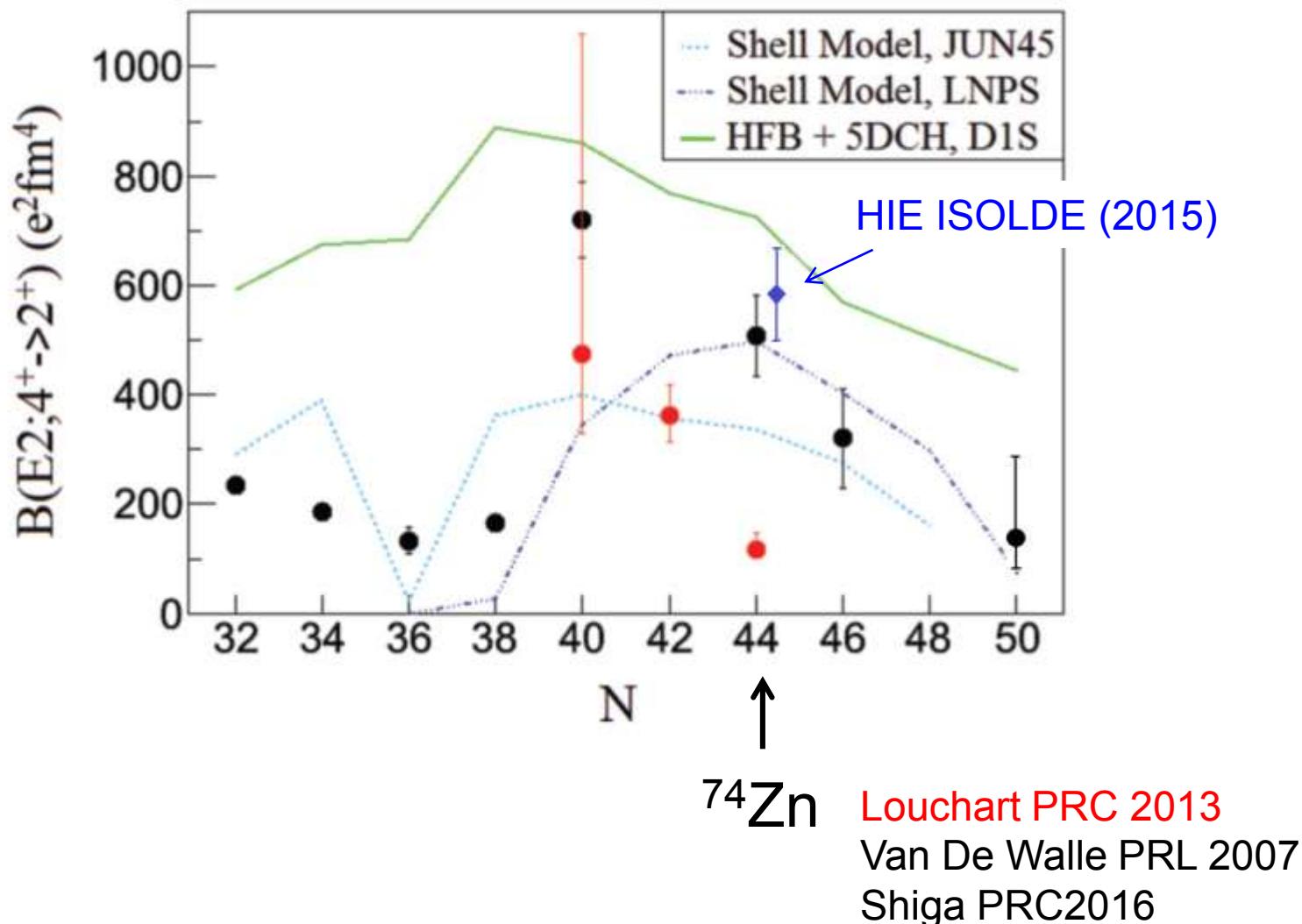
Piet Van Duppen

First Coulex experiment at HIE ISOLDE 10/2015



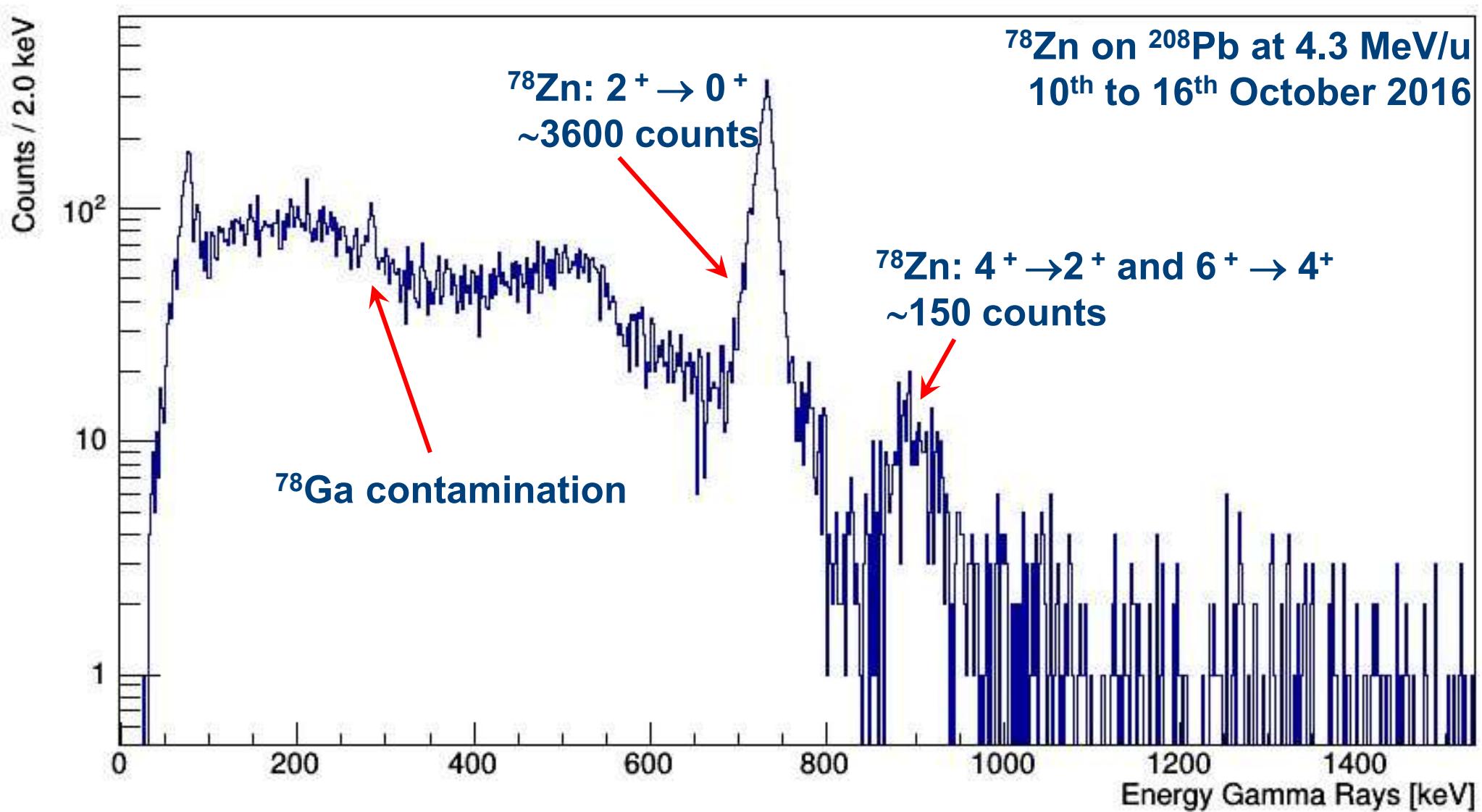
First Coulex experiment at HIE ISOLDE 10/2015

An unexpectedly long lifetime of $20^{+1.8}_{-5.2}$ ps was measured for the 4^+ state in ^{74}Zn .

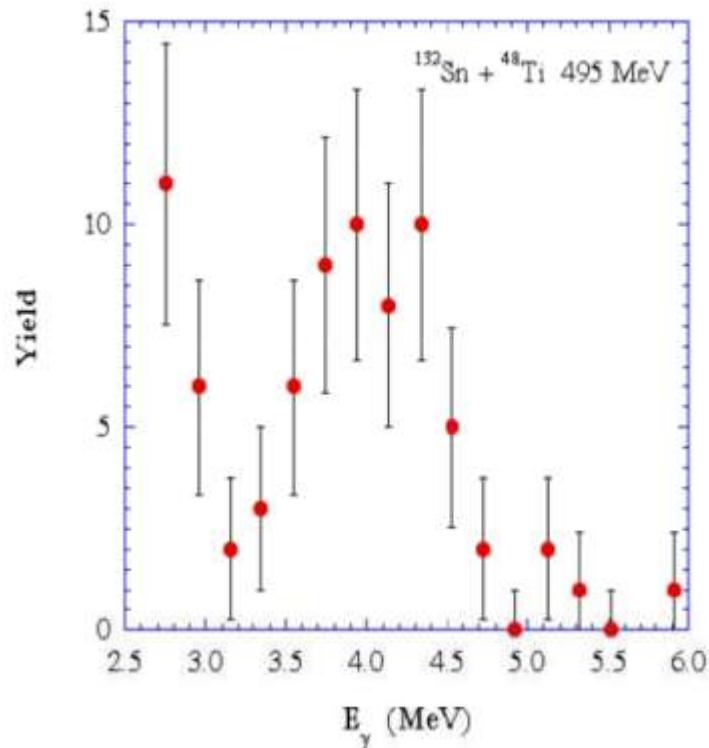


Coulex experiment at HIE ISOLDE second part

Preliminary results IS557 – Oct 2016



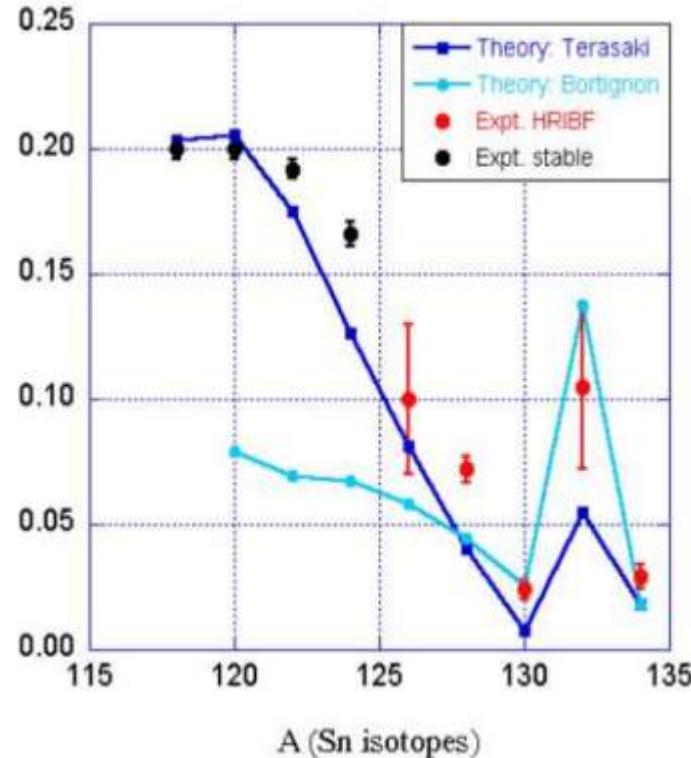
IS551 Coulomb Excitation of ^{132}Sn



R.L. Varner et al., EPJA 25 s01, 391 (2005)

Oak ridge beam time

- ^{132}Sn beam:
 - 1.3×10^5 ions/s, 96% pure.
 - 3.75 MeV/u, 3.56 MeV/u.
- ^{48}Ti target, $Z=22$.
- high efficiency BaF_2 array ($\varepsilon \sim 30\%$).
- two weeks beam time
- particle gamma coincidences



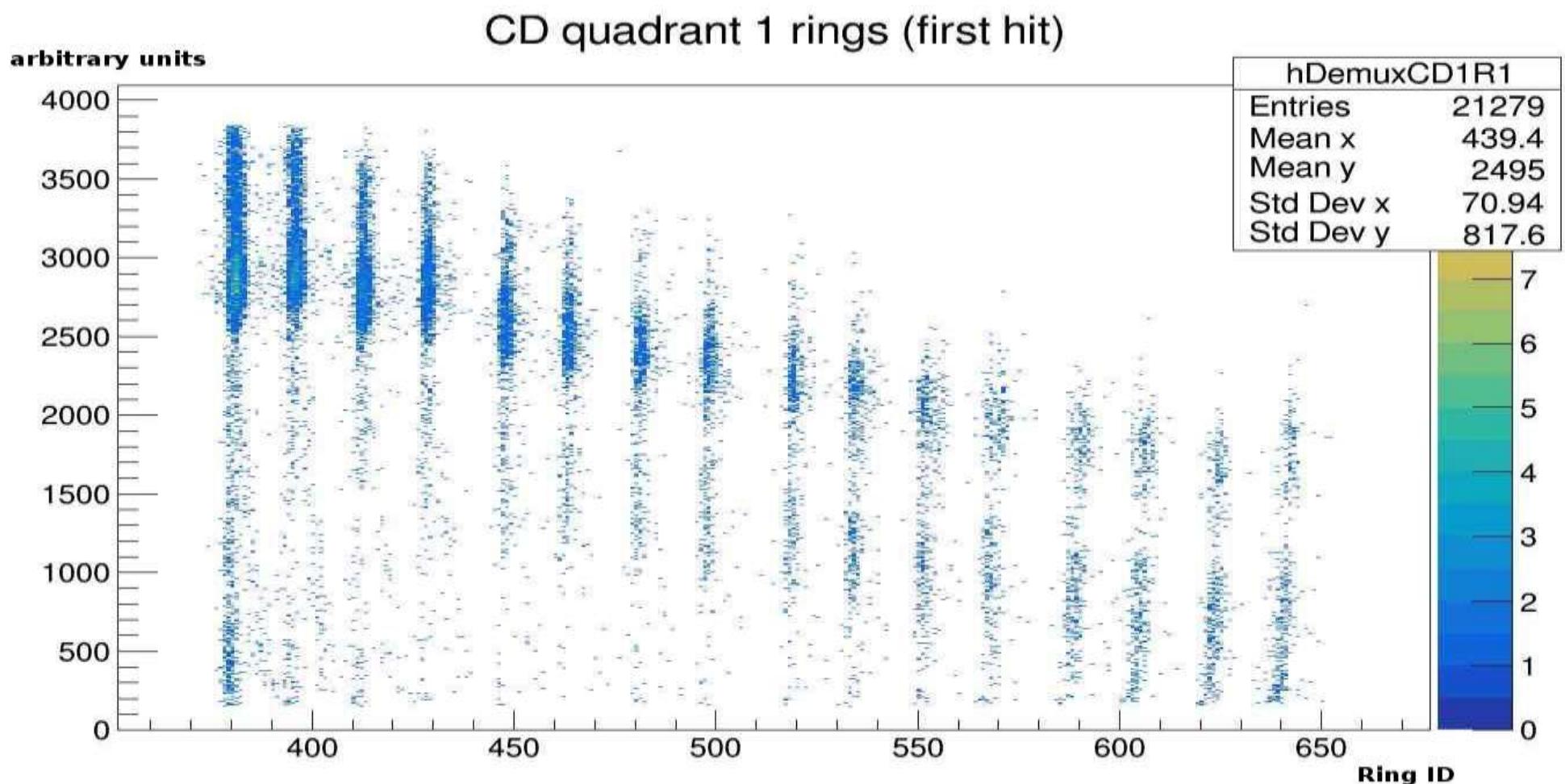
ISOLDE beam time, Oct. 2016

- ^{132}Sn beam:
 - $1 - 3 \times 10^5$ ions/s, ? % pure.
 - 5.5 MeV/u.
- ^{206}Pb target, $Z=82$.
- MINIBALL HPGe array ($\varepsilon \sim 3\%$)
- energy & efficiency calibration @ 4 MeV (^{66}Ga)
- 6 days beam time
- particle gamma coincidences

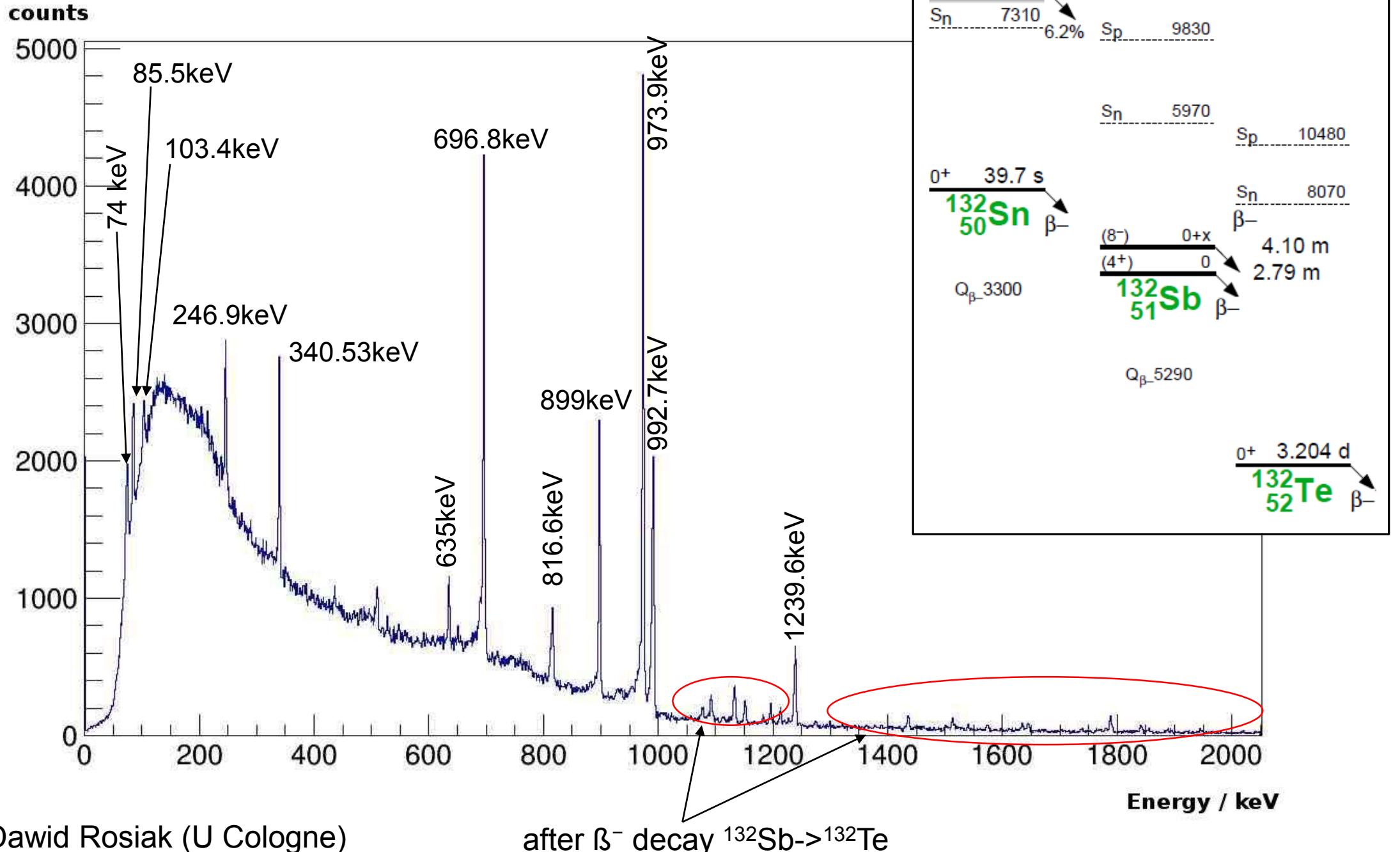
IS551 Coulomb Excitation of ^{132}Sn

$^{132}\text{Sn} + ^{206}\text{Pb}$

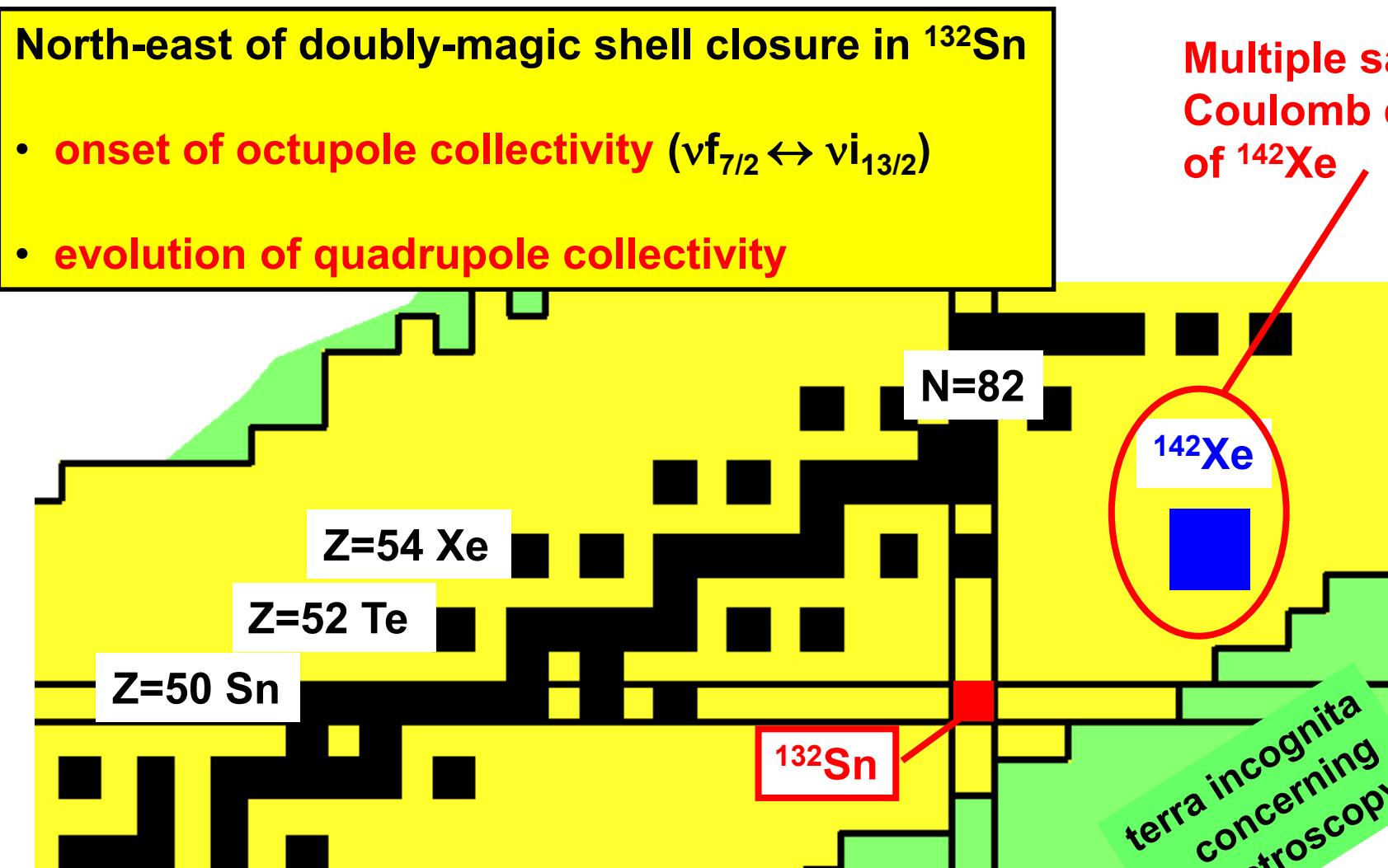
- beam energy 5.5 MeV/u, Oct. 2016
- online analysis



Coulomb Excitation of ^{132}Sn



IS548 - Region of Interest



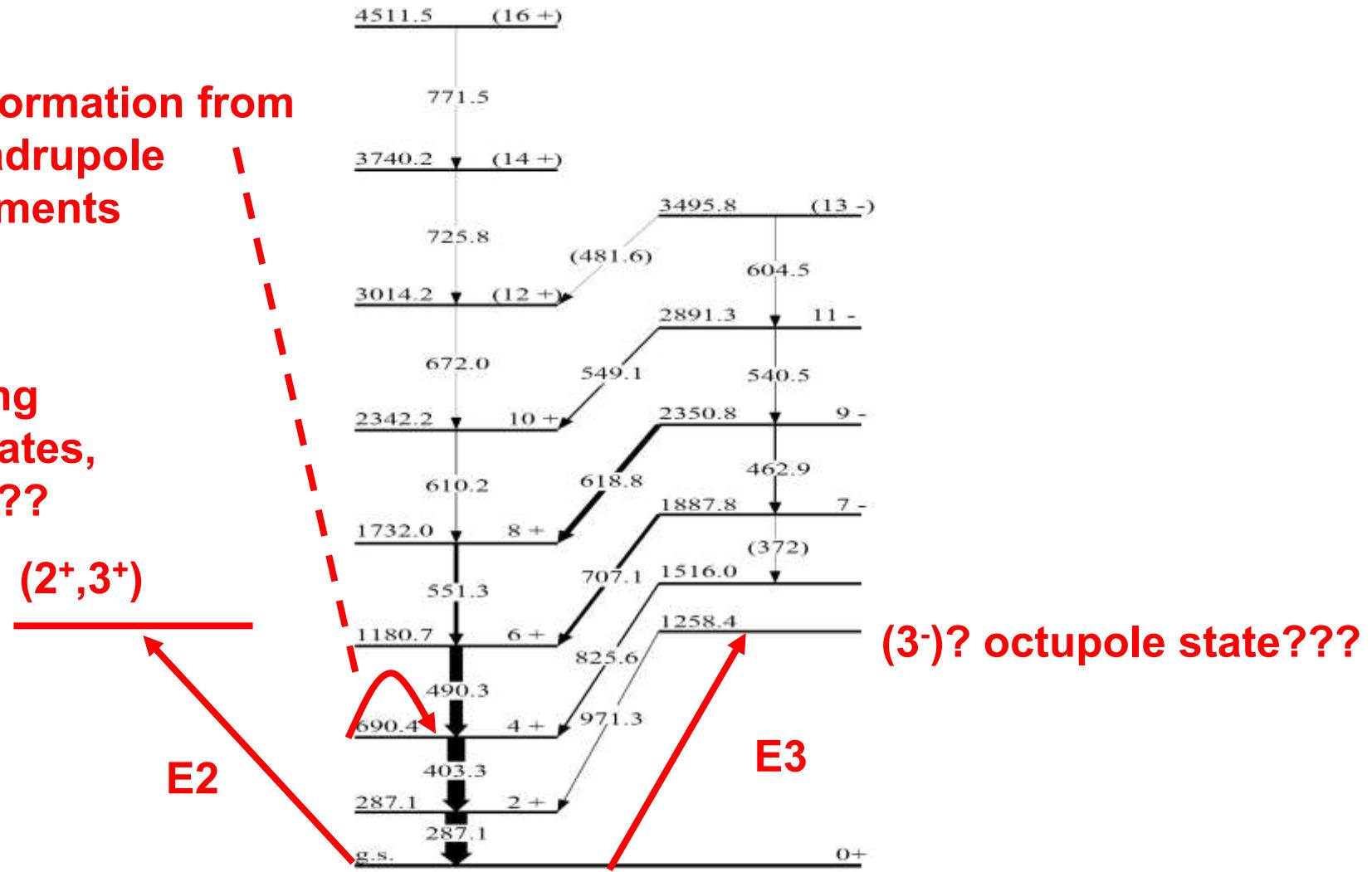
Multiple safe
Coulomb excitation
of ^{142}Xe

Collectivity in ^{142}Xe



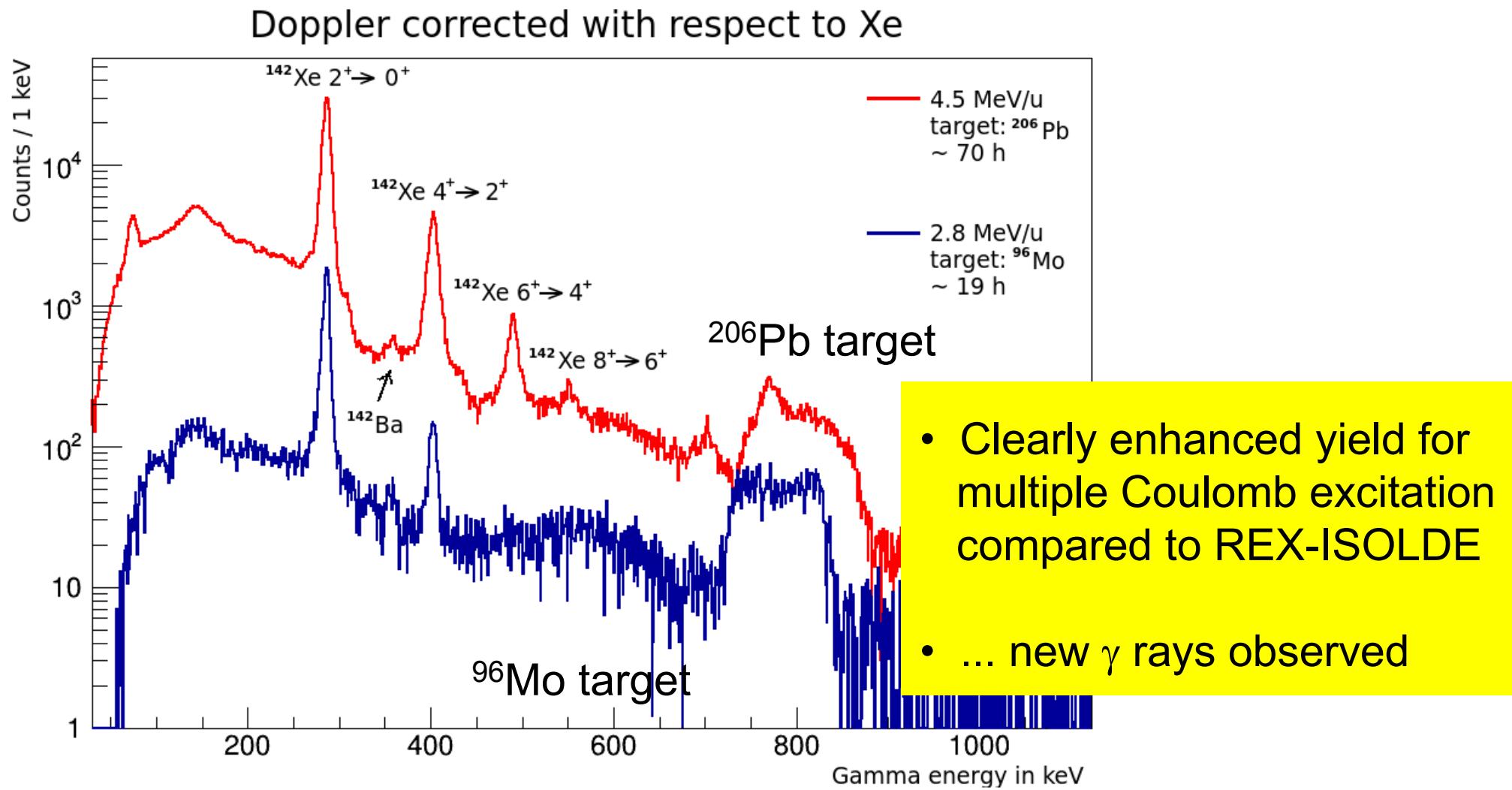
TECHNISCHE
UNIVERSITÄT
DARMSTADT

Deformation from quadrupole moments
New low-lying collective states, e.g. γ band???



W. Urban et al.,
EPJA A 16, 303 (2003)

Online spectrum



Courtesy by Corinna Henrich (TU Darmstadt)

Summary

MINIBALL @ REX-ISOLDE

- Physics case covers chart of nuclei up to ^{224}Ra
- Coulomb excitation & transfer reactions at 3.0 MeV/A

MINIBALL @ HIE-ISOLDE

- First experiments at beam energies up to 5.5 MeV/A
- Coulomb excitation ^{74}Zn
- Online results from ^{78}Zn , ^{110}Sn , ^{132}Sn , ^{142}Xe

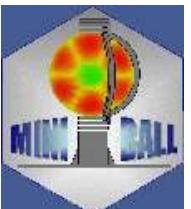
Future of MINIBALL

- BGO shields, SPEDE conversion electrons, plunger, new digital electronics
- A lot of beam time, >48 approved experiments

GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung



The Miniball spectrometer

N. Warr^{1,a}, J. Van de Walle^{2,3}, M. Albers^{1,b}, F. Ames⁴, B. Bastin^{5,c}, C. Bauer⁶, V. Bildstein^{7,8,d}, A. Blazhev¹, S. Bönig⁶, N. Bree⁵, B. Bruyneel^{1,e}, P.A. Butler⁹, J. Cederkäll^{2,10}, E. Clément^{2,11}, T.E. Cocolios^{2,5}, T. Davinson¹², H. De Witte⁵, P. Delahaye², D.D. DiJulio¹⁰, J. Diriken^{5,13}, J. Eberth¹, A. Ekström¹⁰, J. Elseviers⁵, S. Emhofer⁴, D.V. Fedorov¹⁴, V.N. Fedosseev², S. Franchoo^{2,f}, C. Fransen¹, L.P. Gaffney⁹, J. Gerl¹⁵, G. Georgiev¹⁶, R. Gernhäuser⁸, T. Grahn^{9,17,18}, D. Habs⁴, H. Hess¹, A.M. Hurst^{9,19}, M. Huyse⁵, O. Ivanov^{5,g}, J. Iwanicki^{9,20}, D.G. Jenkins^{9,21}, J. Jolie¹, N. Kesteloot^{5,13}, O. Kester⁴, U. Köster², M. Krauth²², T. Kröll^{6,8}, R. Krücken^{8,h}, M. Lauer⁷, J. Leske⁶, K.P. Lieb²³, R. Lutter⁴, L. Maier⁸, B.A. Marsh², D. Mücher^{1,8}, M. Münch⁸, O. Niedermaier⁷, J. Pakarinen^{2,9,17,18}, M. Pantea⁶, G. Pascovici¹, N. Patronis⁵, D. Pauwels⁵, A. Petts⁹, N. Pietralla⁶, R. Raabe⁵, E. Rapisarda^{2,5}, P. Reiter¹, A. Richter⁶, O. Schaile⁴, M. Scheck^{6,9}, H. Scheit^{6,7}, G. Schrieder⁶, D. Schwalm⁷, M. Seidlitz¹, M. Seliverstov^{2,5,14,24,i}, T. Sieber², H. Simon⁶, K.-H. Speidel²⁵, C. Stahl⁶, I. Stefanescu^{5,26}, P.G. Thirolf⁴, H.-G. Thomas¹, M. Thürauf⁶, P. Van Duppen⁵, D. Voulot²⁷, R. Wadsworth²¹, G. Walter^{22,28}, D. Weißhaar^{1,j}, F. Wenander²⁷, A. Wiens^{1,k}, K. Wimmer^{8,l}, B.H. Wolf⁴, P.J. Woods¹², K. Wrzosek-Lipska^{5,20}, and K.O. Zell¹