STUDIES OF EXOTIC NUCLEI AT RIKEN WITH MINOS

A. Corsi

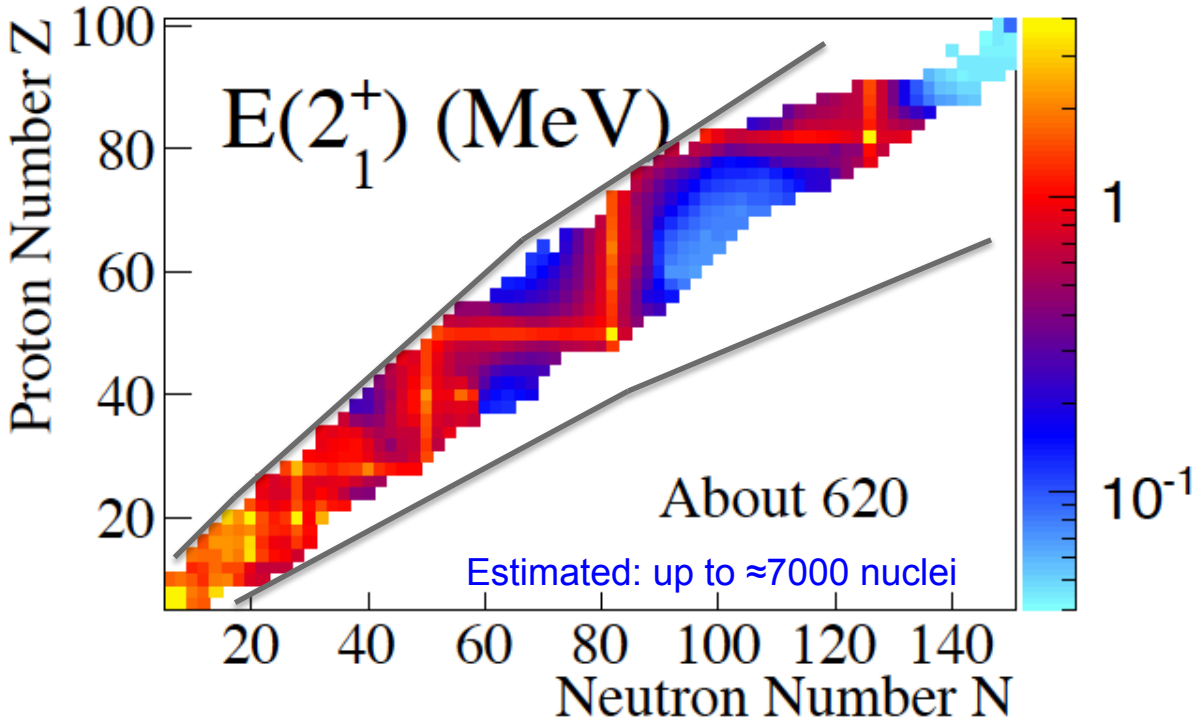
CEA Saclay

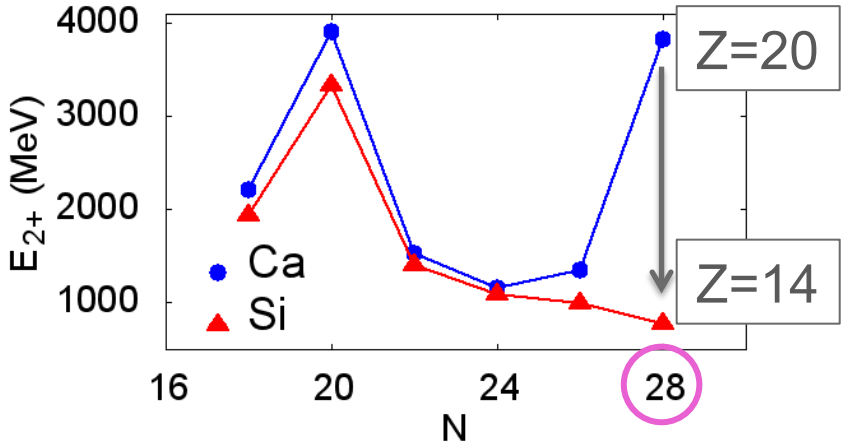
Conseil scientifique de l'Irfu, January 15th 2015

Outline

- What we learn from exotic nuclei
- The MINOS device
- MINOS physics program at RIKEN:
  - SEASTAR (1/3: May 2014)
  - 2-neutron correlation in Borromean nuclei (Dec.2014)
  - ^{28}O invariant mass
- Perspectives

Spectroscopy of exotic nuclei





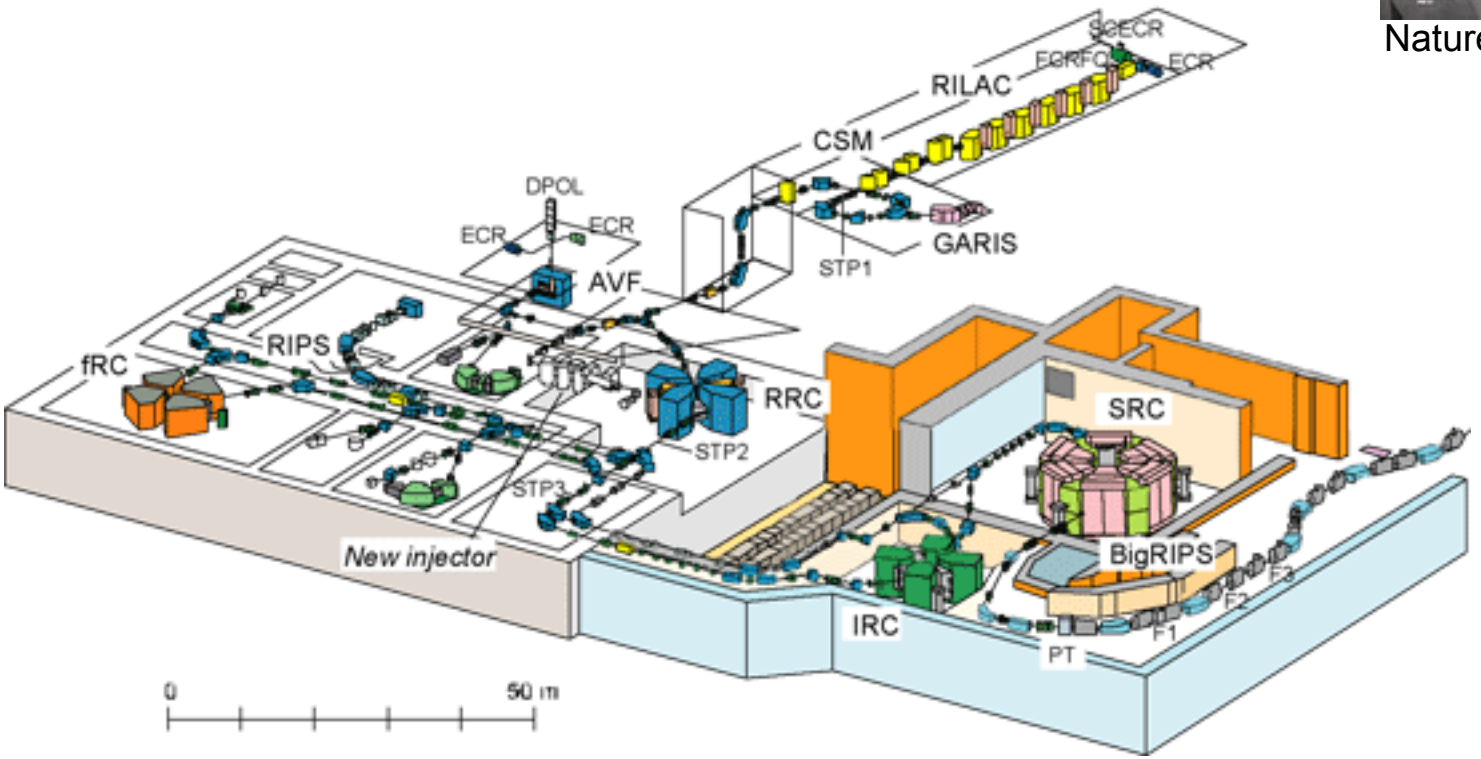
POSSIBLE DRIVING MECHANISMS:

- Central force T. Otsuka *et al.*, PRL 87 (2001)
- Tensor force T. Otsuka *et al.*, PRL 104 (2010)
- 3 body force G. Hagen *et al.*, PRC **80** (2009)

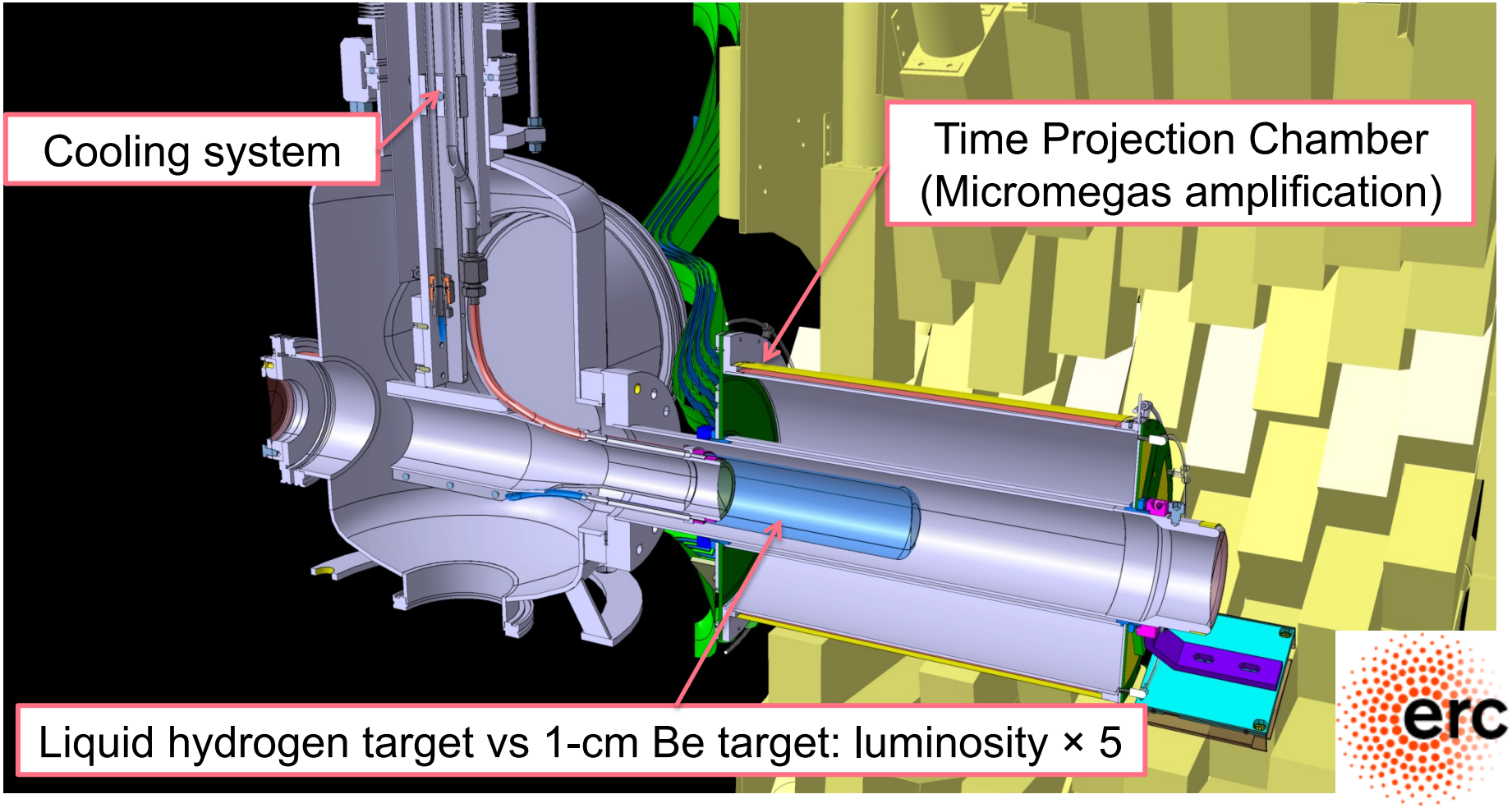
RIBF facility at RIKEN

Primary beam	Energy (MeV/u)	Secondary beam (N/Z)	*i* (pps)
^{48}Ca	350	**^{41}Al (2.1)**	1 *(2014)*
^{70}Zn	350	**^{55}Sc (1.7)**	12 *(2012)*
^{238}U	350	**^{79}Cu (1.7)**	5 *(2014)*

Nature 502 (2013)



MINOS : Magic Numbers Off Stability

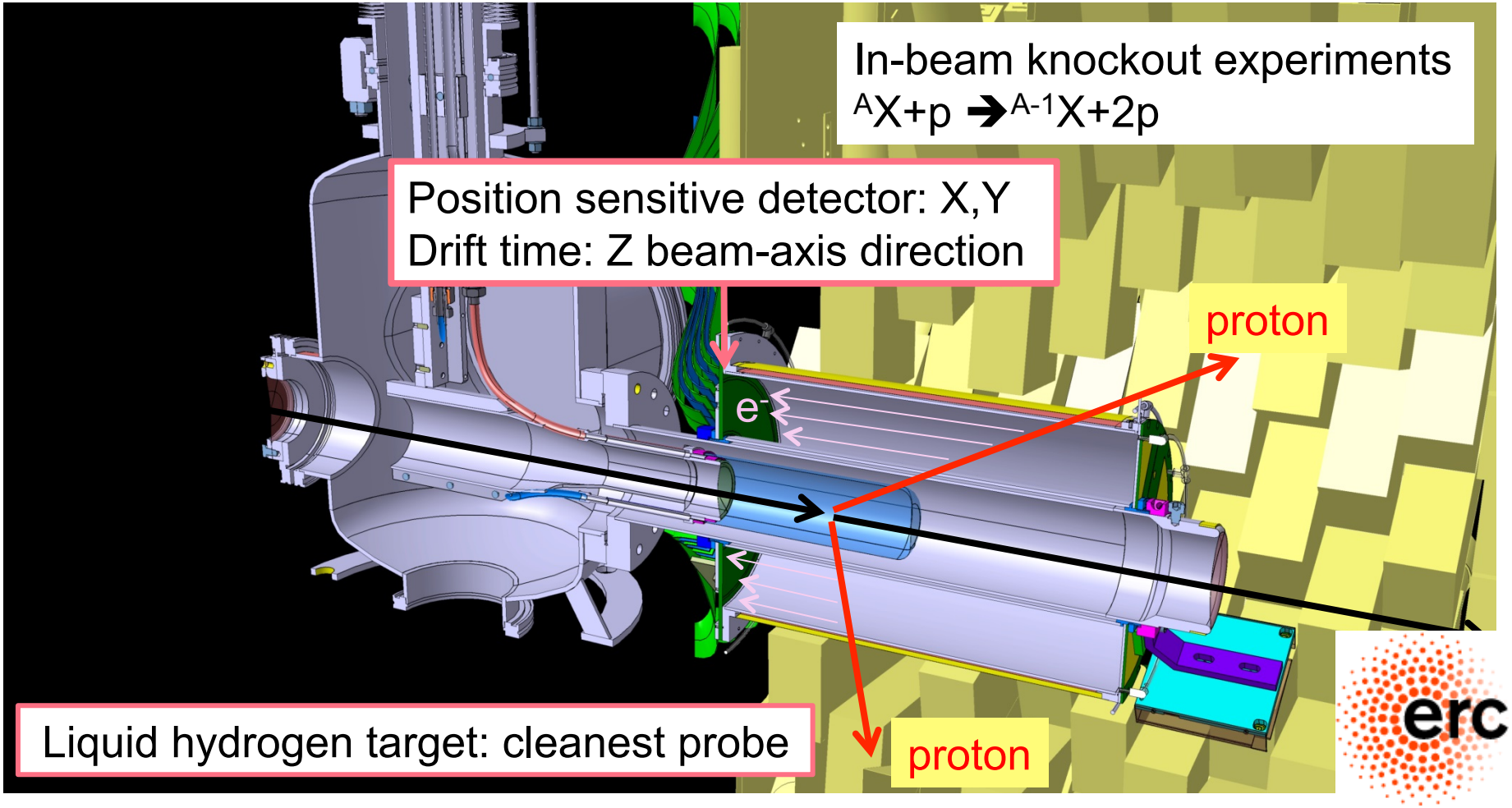


A. Obertelli *et al.,* Eur. Phys. Jour. A **50**, 8 (2014)

http://minos.cea.fr

Hosted by Spin-Isospin Laboratory of RIKEN Nishina Center

MINOS : Magic Numbers Off Stability



A. Obertelli *et al.,* Eur. Phys. Jour. A **50**, 8 (2014)

http://minos.cea.fr

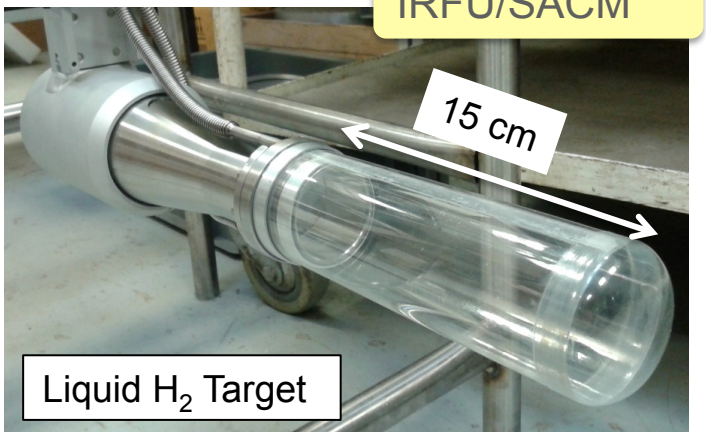
Hosted by Spin-Isospin Laboratory of RIKEN Nishina Center

The MINOS device

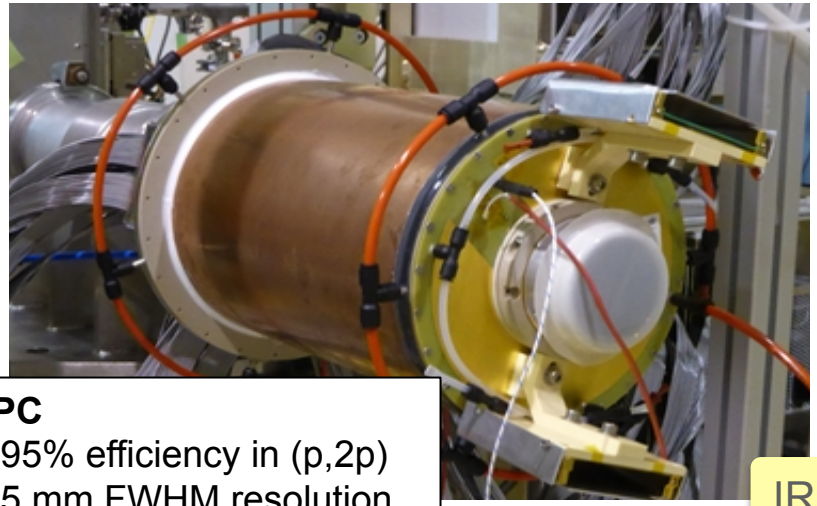
3 YEARS OF DEVELOPEMENT, 1 YEAR OF PHYSICS

2010	ERC grant, PI: A. Obertelli
2011	simulations and design construction proposal endorsed by RIBF NP-PAC
2012	construction MOU between RIKEN Nishina Center and DSM
2013	in beam validation at HIMAC experiments approved by RIBF NP-PAC *(spokespersons: CEA-RNC-CNS-TiTech)*
2014	first two experiments at RIBF

IRFU/SACM



Micromegas detector
~4000 pads



TPC
> 95% efficiency in (p,2p)
< 5 mm FWHM resolution

Front-End card with 4 AGET* chips

IRFU/SéDI

readout card FEMINOS

*GET project, ANR 2010

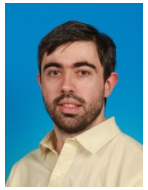
MINOS : a CEA/IRFU development

Development & Physics


A. Obertelli (PI)


A. Corsi


E. Pollacco

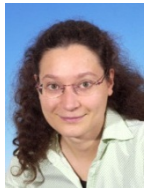

L. Audirac
Postdoc (2011-13)


C. Santamaria
PhD (2012-15)


B. Bryuneel
Postdoc (2011-13)

Physics


A. Gillibert


V. Lapoux

IRFU/SPhN

Detector


A. Delbart


A. Peyaud


J.P. Mols


A. Giganon


C. Lahonde

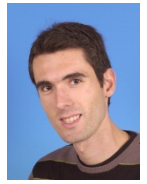

G. Prono

Electronics / DAQ


D. Calvet


S. Anvar


F. Druillole
(<2012)


F. Chateau

IRFU/SéDI

CC & mechanics


J.-Y. Rousse


D. Loiseau


D. Leboeuf

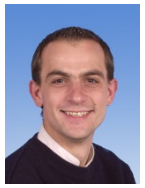

C. Péron


A. Mohamed
(<2013)

IRFU/SIS

Target

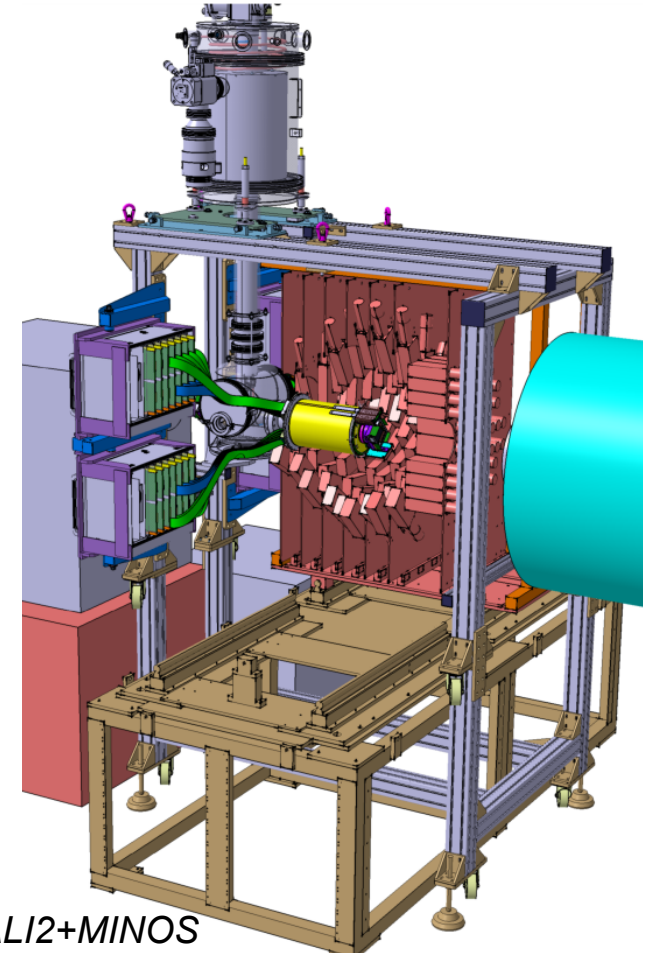

J.-M. Gheller


G. Authelet

IRFU/SACM

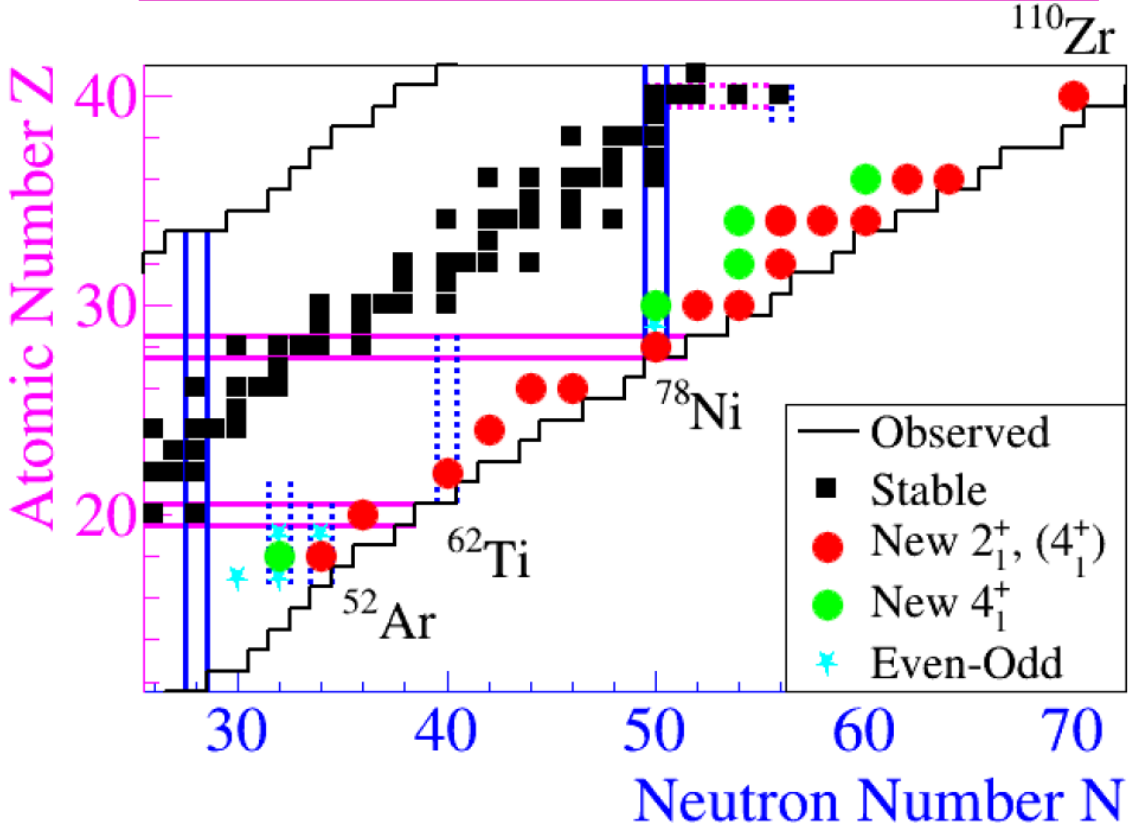
Shell Evolution and Search for Two-plus Energies At the RIBF (SEASTAR)

Spokespersons: P. Doornenbal (RIKEN), A. Obertelli (CEA, RIKEN JSPS fellow)



DALI2+MINOS

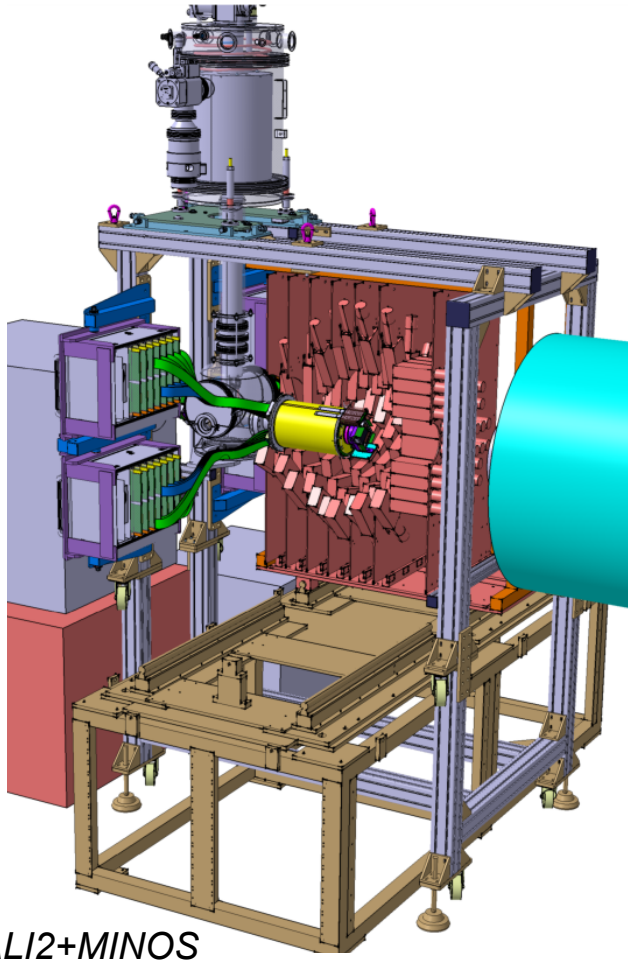
Full program: 30 days of beam time



Proposal for a Scientific Program promoted by H.Sakurai (RNC, Univ. of Tokyo) and T.Uesaka (RNC)

Shell Evolution and Search for Two-plus Energies At the RIBF (SEASTAR)

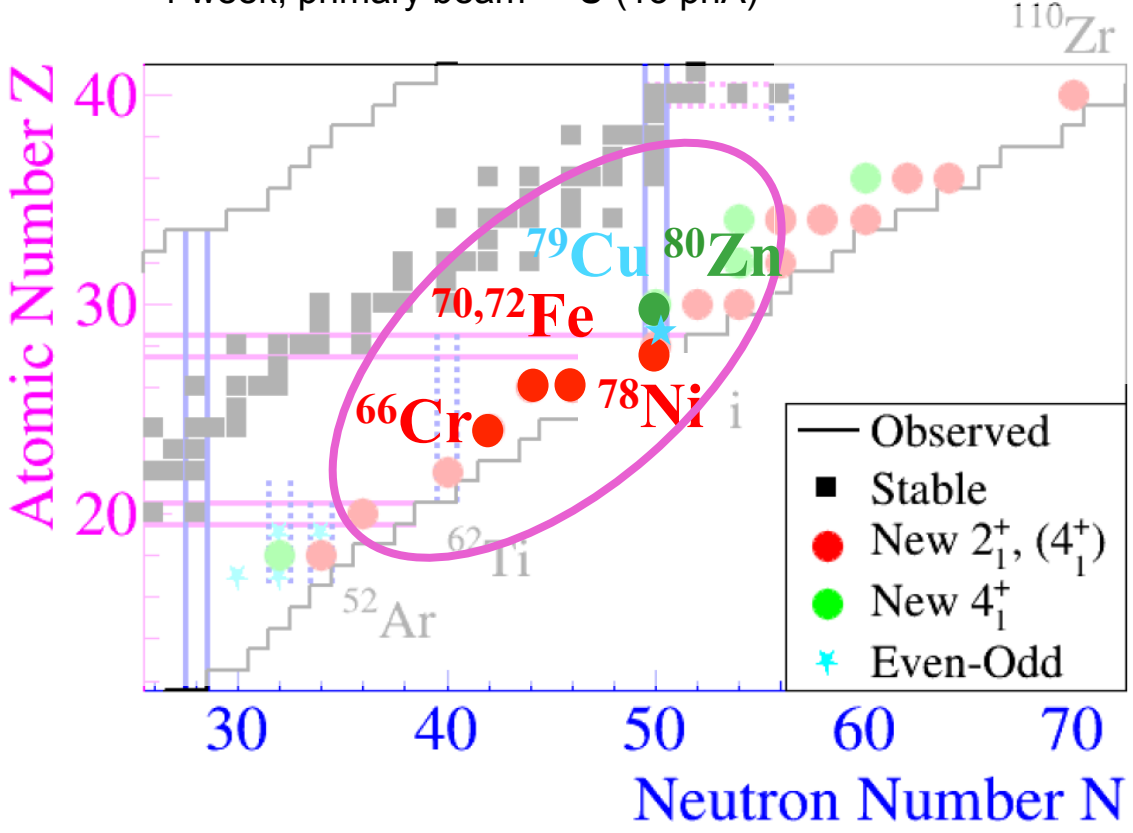
Spokespersons: P. Doornenbal (RIKEN), A. Obertelli (CEA, RIKEN JSPS fellow)



DALI2+MINOS

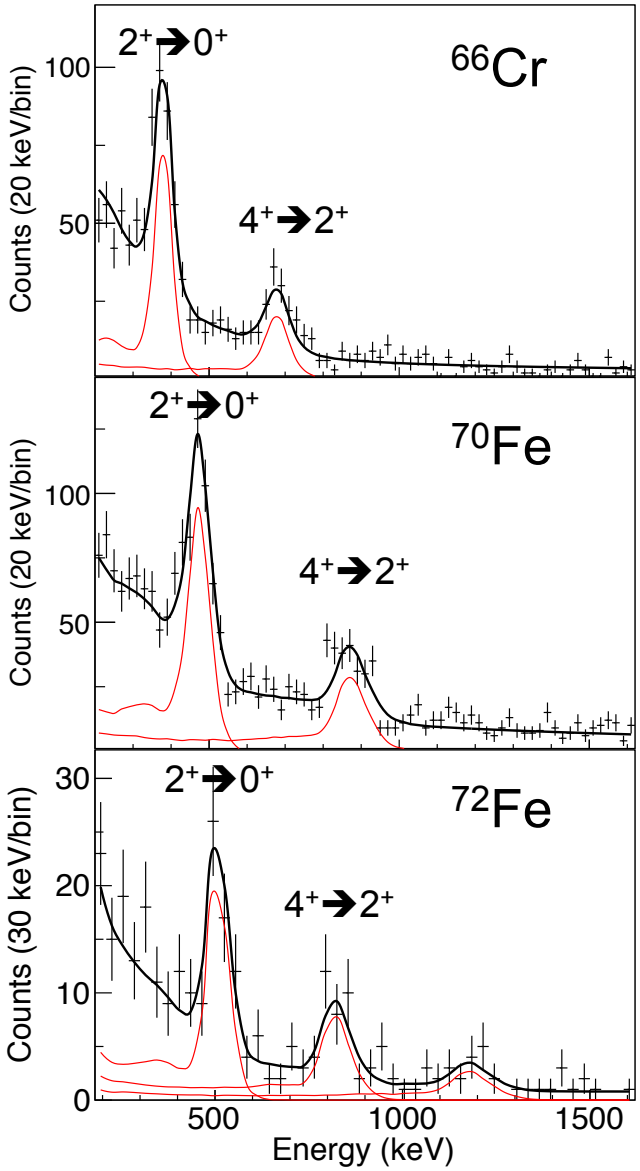
May 2014: SEASTAR 1/3 (high priority)

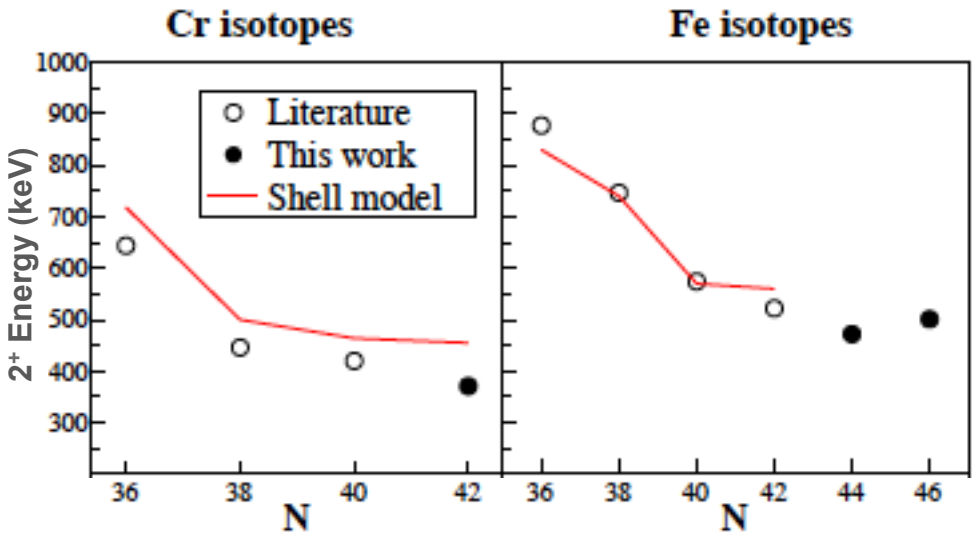
1 week, primary beam ^{238}U (13 pnA)



Dec. 2014: SEASTAR reviewed by NP-PAC, SEASTAR 2/3 HIGH PRIORITY

SEASTAR 1/3: Island of inversion at N=40



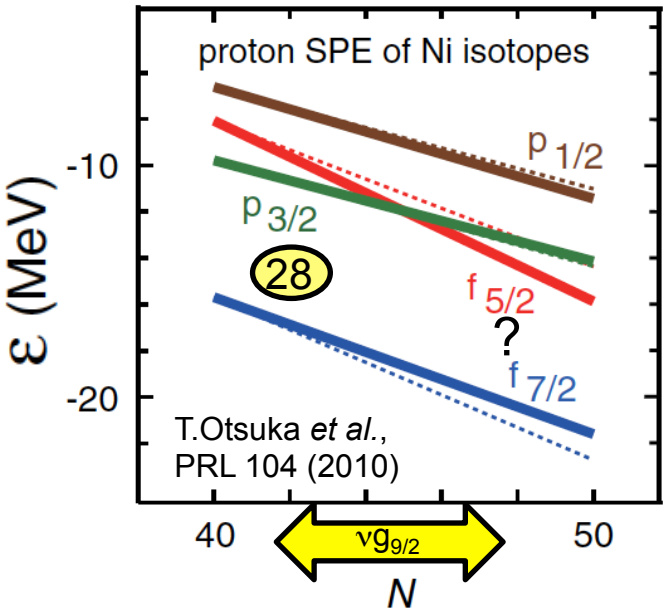


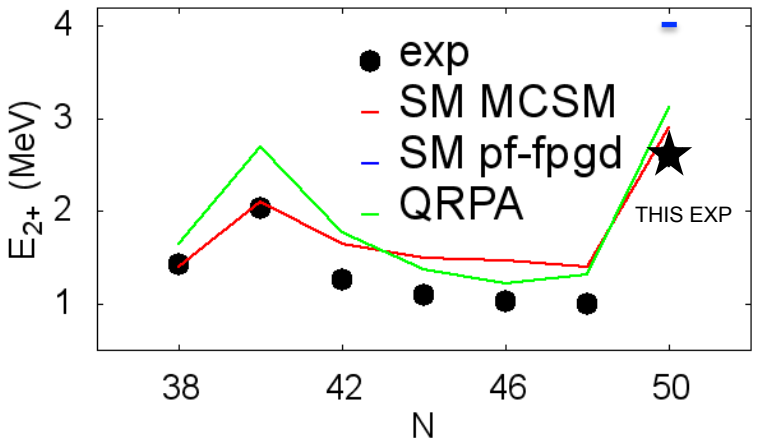
Courtesy of C.Santamaria (CEA) and C.Louchart (TU Darmstadt)
Ongoing collaboration with F.Nowacki (IPHC Strasbourg)

- **Collectivity plateau at N≥40**
- **Analogy with N≥20 island of inversion**

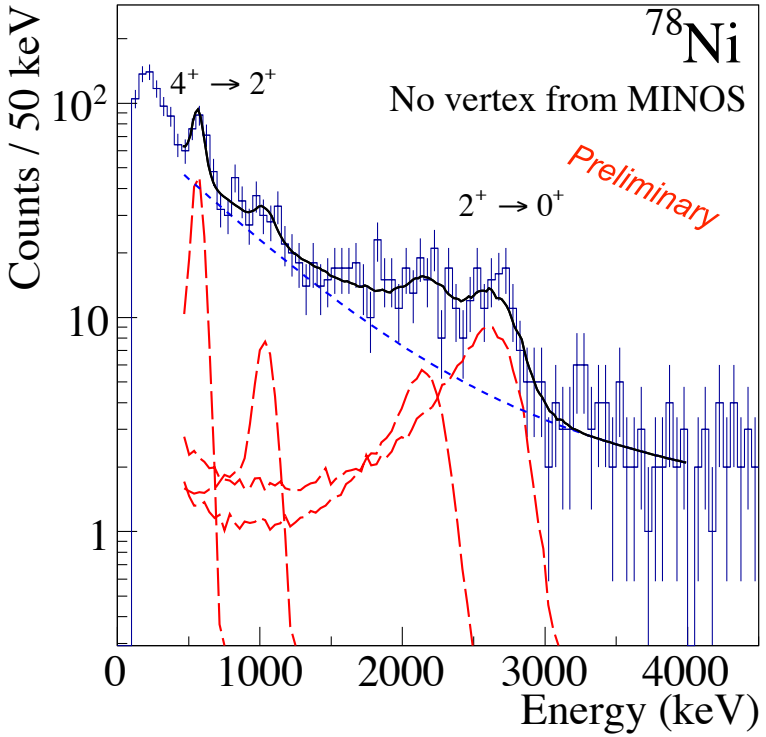
C.Santamaria et al., in preparation

SEASTAR 1/3: Shell closure at Z=28 and N=50?





MCSM T. Tsunoda *et al., PRC 89 (2014)*
SM pf-fpgd K.Siejia and F.Novacki, PRC 85 (2012)
QRPA S. Péru *et al.*, EPJA 50 (2014)



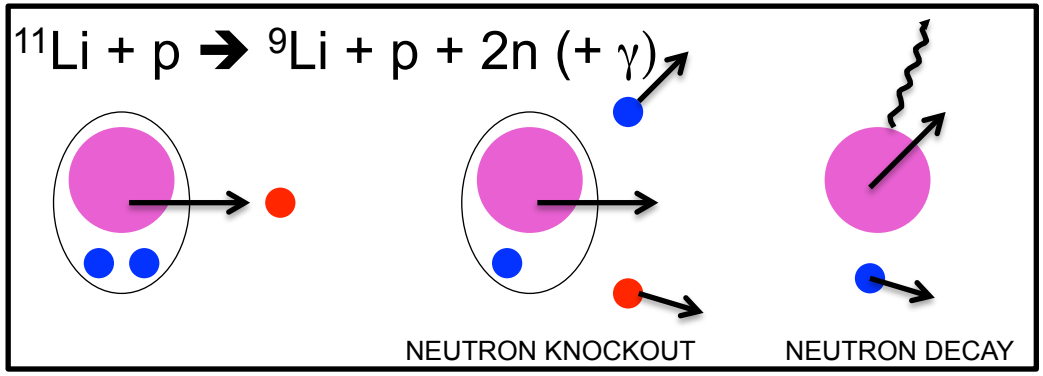
Courtesy of P.Doornenbal (RIKEN) and R.Taniuchi (Univ. of Tokyo)

- Analysis ongoing
- Data interpretation with T.Otsuka (CNS and Univ. of Tokyo) and A.Schwenk (TU Darmstadt)

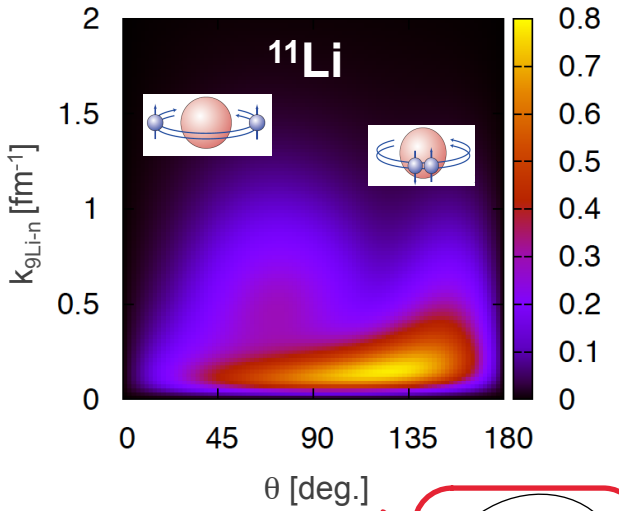
Nature of di-neutron correlations in borromean nuclei

Spokespersons: Y. Kubota (CNS and RIKEN), A. Corsi (CEA)

Dec. 2014

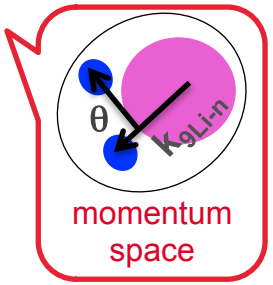


Y.Kikuchi (RIKEN Nishina Center), private comm.



UNIQUE EXPERIMENT:

- High momentum transfer ➔ **minimize final state interaction**
- **Kinematically complete** measurement
- Core excitation via γ detection

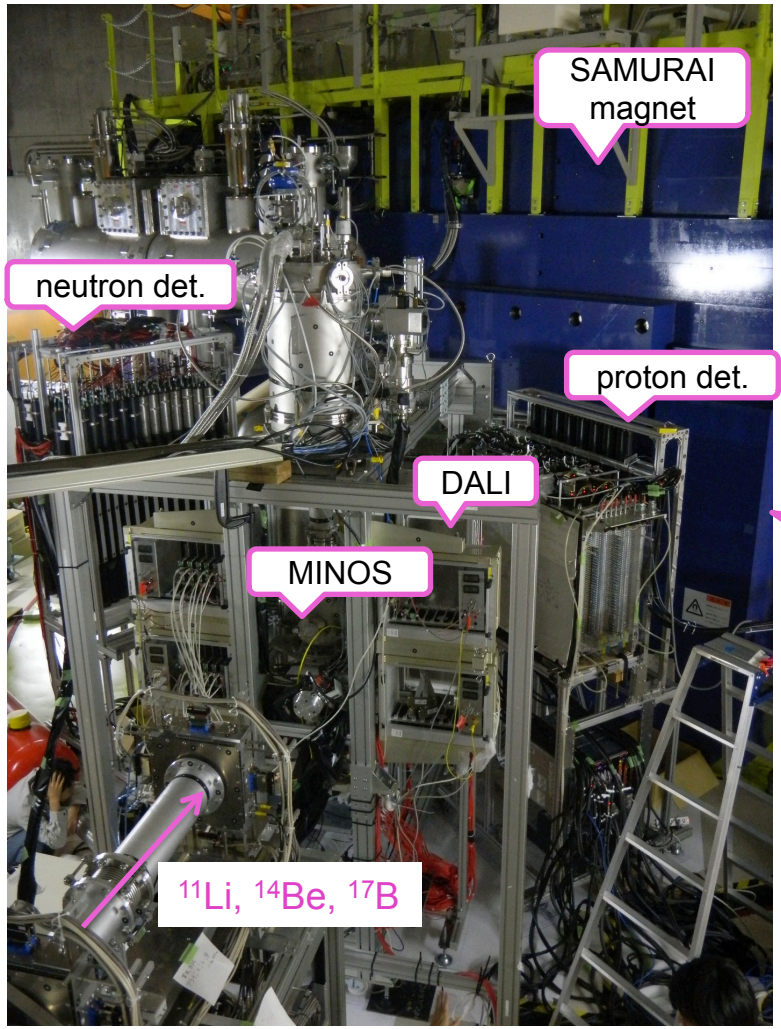


➔ Need high statistics : RIBF + MINOS thick target (**luminosity × 100**)

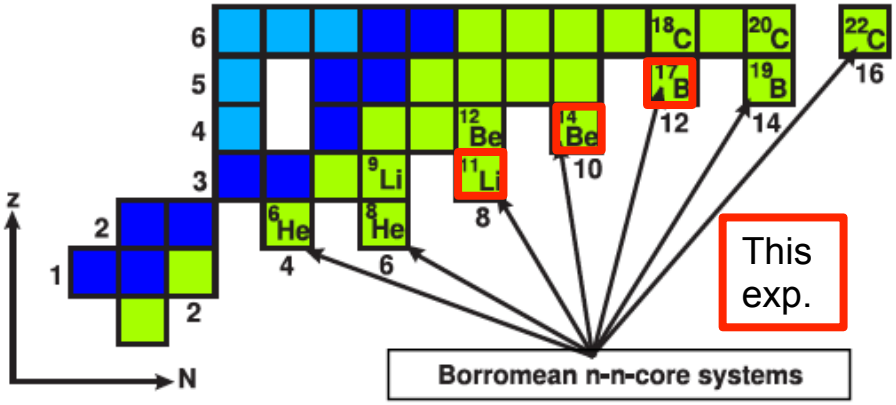
GOAL: 10^5 p×n×n×^{9}Li coincidences

Nature of di-neutron correlations in borromean nuclei

SETUP AT SAMURAI, Dec. 2014



+NEBULA (neutrons) and hodoscope for fragments



- ✓ 2 month preparation,1 week beam
- ✓ 2 × 10^5 pps: ^{11}Li (60%), ^{14}Be(10%), ^{17}B (8%)
- ✓ 15-cm LH_2 target
- ✓ **≈ 10^5 p×n×n×^{9}Li coincidences**

Perspectives

Highlights of future MINOS experiments:

- spectroscopy of ^{110}**Zr along r-process**

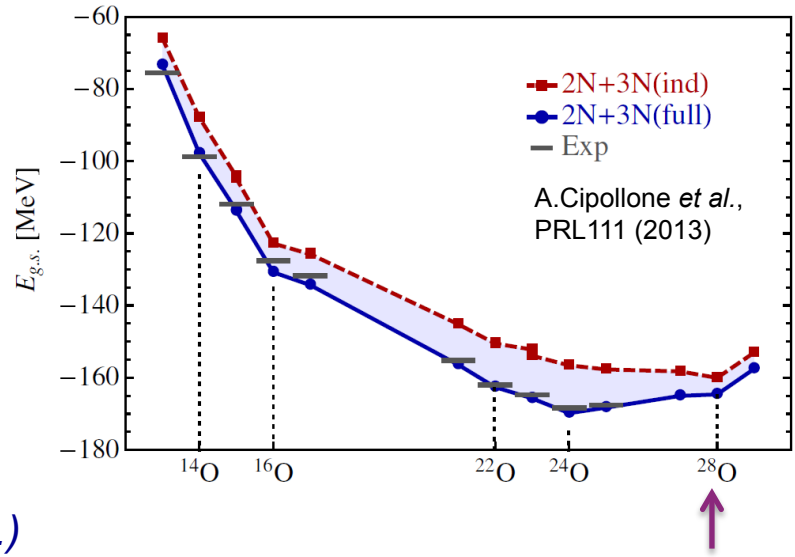
  (*2015*, SEASTAR 2/3*)
- shell closure at **N=34** below ^{54}Ca
- shell closure at **N=40** near ^{60}Ca

  (*2016*, SEASTAR 3/3*)
- role of 3-body forces: ^{28}**O** invariant mass

  (2015*, *Spokesperson: Y. Kondo, Tokyo Tech.)*
- spectroscopy of ^{100}**Sn**

  (*~2017, to be proposed)*

**approved, not scheduled yet*



Follow-up of MINOS program:

- Extension of MOU DSM-RIKEN Nishina Center in 2016-2018

- Invariant mass experiments at RIBF

  N. Orr, ANR 2014 EXPAND (LPC – RIKEN – TiTech – CEA – IPNO)
- Missing mass spectroscopy at RIBF

  A. Corsi, NUCLEI proposal submitted to ANR 2015

Collaborations

MINOS development and local teams

S. Anvar, L. Audirac, G. Authelet, H. Baba, B. Bruyneel, D. Calvet, F. Chateau, A. Corsi, A. Delbart, P. Doornenbal, J.-M. Gheller, A. Giganon, T. Isobe, Y. Kubota, C. Lahonde-Hamdoun, D. Leboeuf, D. Loiseau, M. Matsushita, A. Mohamed, J.-Ph. Mols, T. Motobayashi, M. Nishimura, A. Obertelli, S. Ota, H. Otsu, C. Péron, A. Peyaud, E.C. Pollacco, G. Prono, J.-Y. Rousse, H. Sakurai, C. Santamaria, M. Sasano, R. Taniuchi, S. Takeuchi, T. Uesaka, Y. Yanagisawa, K. Yoneda

Physics collaborations

Di-neutron correlations Uesaka, Sasano, Zenihiro, Yoneda, Sato, Otsu, Shimizu, Baba, Isobe, Sako, Stul, Panin (RNC), **Kubota**, Dozono, Ota, Kobayashi M., Kiyokawa (CNS), **Corsi**, Obertelli, Santamaria, Pollacco, Lapoux, Gillibert, Calvet, Delbart, Gheller, Authelet, Roussé (CEA), Kobayashi N., Koyama, Miyazaki (Tokyo Univ.), Kobayashi T., Hasegawa, Sumikama (Tohoku Univ.), Nakamura, Kondo, Togano, Shikata, Tsubota, Saito, Ozaki (Tokyo Tech), Yasuda, Sakaguchi, Shindo, Tabata, Ohkura, Nishio (Kyushu Univ.), Nakatsuka (Kyoto Univ.),Yukie, Kawakami, Kanaya (Miyazaki Univ.), Marques, Gibelin, Orr (LPC Caen), Flavigny (IPNO), Yang, Feng (Peking Univ.), Caesar, Paschalis (TUD), Reichert (TUM), Kim (Ehwa Womans University)

Oxygen isotopes Y. Kondo, T. Nakamura, Y. Togano, M. Shikata, J. Tsubota (Tokyo Tech), H. Baba, H. Sato, K. Yoneda, H. Otsu, T. Isobe, M. Sasano, Y. Shimizu, T. Uesaka (RIKEN Nishina Center), T. Kobayashi (Tohoku University), F. Château, D. Calvet, A. Gillibert, J.-M. Gheller, V. Lapoux, A. Peyaud, A. Obertelli, A. Corsi, E.C. Pollacco, C. Santamaria (CEA Saclay), T. Aumann, H. Scheit (TU Darmstadt), N. Orr, J. Gibelin, F.M. Marques, S. Leblond, N.L. Achouri, F. Delaunay (LPC Caen), Y. Satou, S. Kim, J. Hwang (Seoul National University), T. Murakami, N. Nakatsuka (Kyoto University), C.R. Hoffman (Argonne National Laboratory), A. Navin, M. Rejmund, A. Lemasson (GANIL), S. Stephenson (Gettysburg college), H. Simmon (GSI)

SEASTAR N. Alamanos, G. de Angelis, N. Aoi, H. Baba, C. Barbieri, C. Bertulani, A. Corsi, F. Delaunay, Z. Dombradi, **P. Doornenbal**, T. Duguet, S. Franchoo, J. Gibelin, A. Gillibert, S. Go, M. Gorska, A. Gottardo, S. Grévy, J.D. Holt, E. Ideguchi, T. Isobe, A. Jungclaus, N. Kobayashi, T. Kobayashi, Y. Kondo, W. Korten, Y. Kubota, I. Kuti, V. Lapoux, S. Leblond, J. Lee, S. Lenzi, H. Liu, G. Lorusso, C. Louchart, R. Lozeva, F.M. Marques, I. Matea, K. Matsui, Y. Matsuda, M. Matsushita, J. Menendez, D. Mengoni, S. Michimasa, T. Miyazaki, S. Momiyama, P. Morfouace, T. Motobayashi, T. nakamura, D. Napoli, F. Naqvi, M. Niikura, **A. Obertelli**, N. Orr, S. Ota, H. Otsu, T. Otsuka, N. Pietralla, Z. Podolyak, E.C. Pollacco, G. Potel, G. Randisi, F. Recchia, E. Sahin, H. Sakurai, C. Santamaria, M. Sasano, A. Schwenk, Y. Shiga, Y. Shimuzu, S. Shimoura, J. Simonis, P.A. Soderstrom, S. Sohler, V. Soma, I. Stefan, D. Steppenbeck, T. Sumikama, H. Suzuki, M. Tanaka, R. Taniuchi, K.N. Tuan, T. Uesaka, J. Valiente Dobon, Zs. Vajta, D. Verney, H. Wang, V. Werner, Zh. Xu, R. Yokoyama, K. Yoneda