PHYSICS WITH MINOS AT THE RIBF

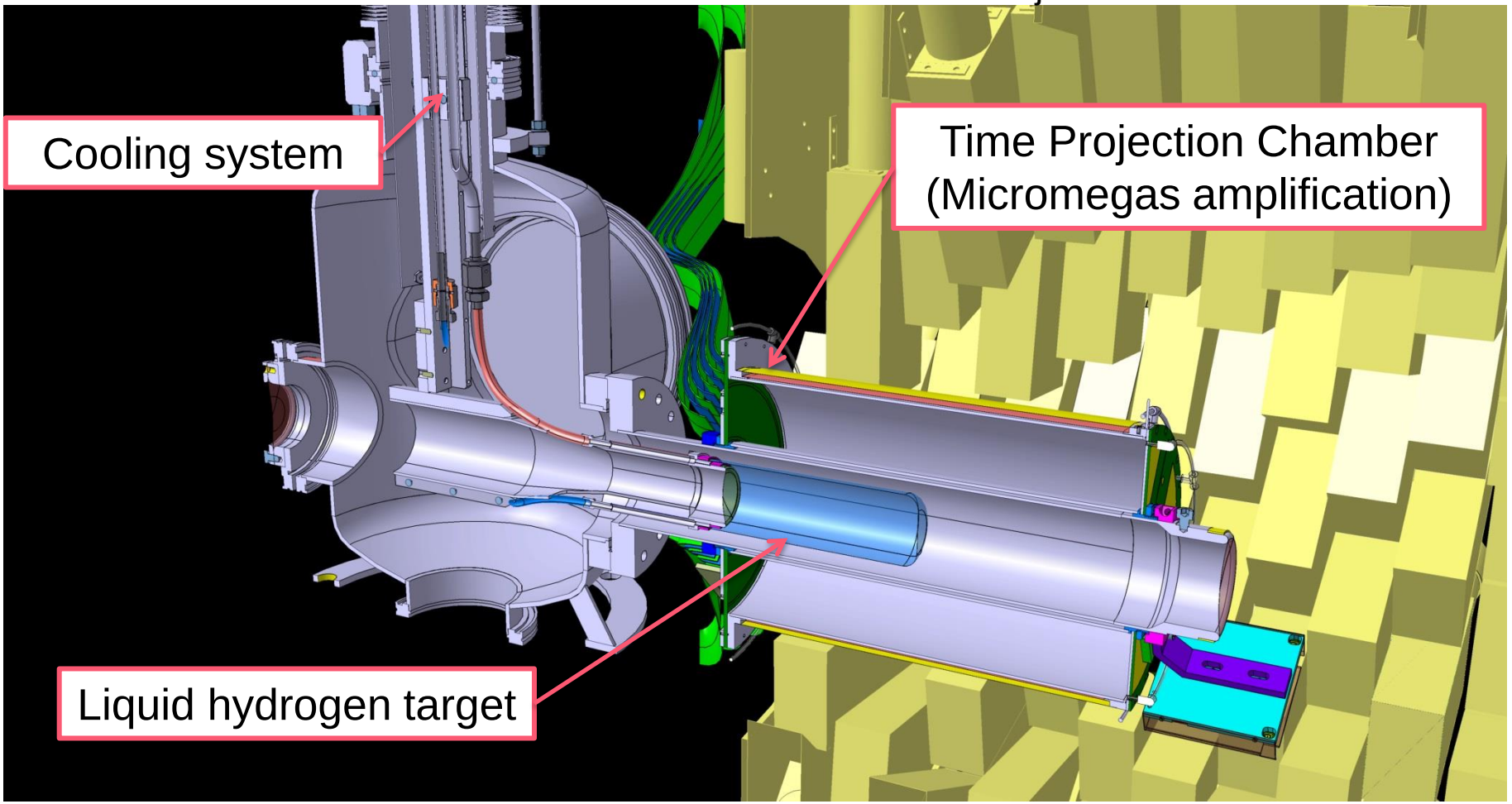
A. Obertelli

CEA Saclay, RIKEN Nishina Center (JSPS fellow)

Conference on Advances in Radioactive Isotopes Science ARIS 2014

MINOS : Magic Numbers Off Stability

Project started in November 2010

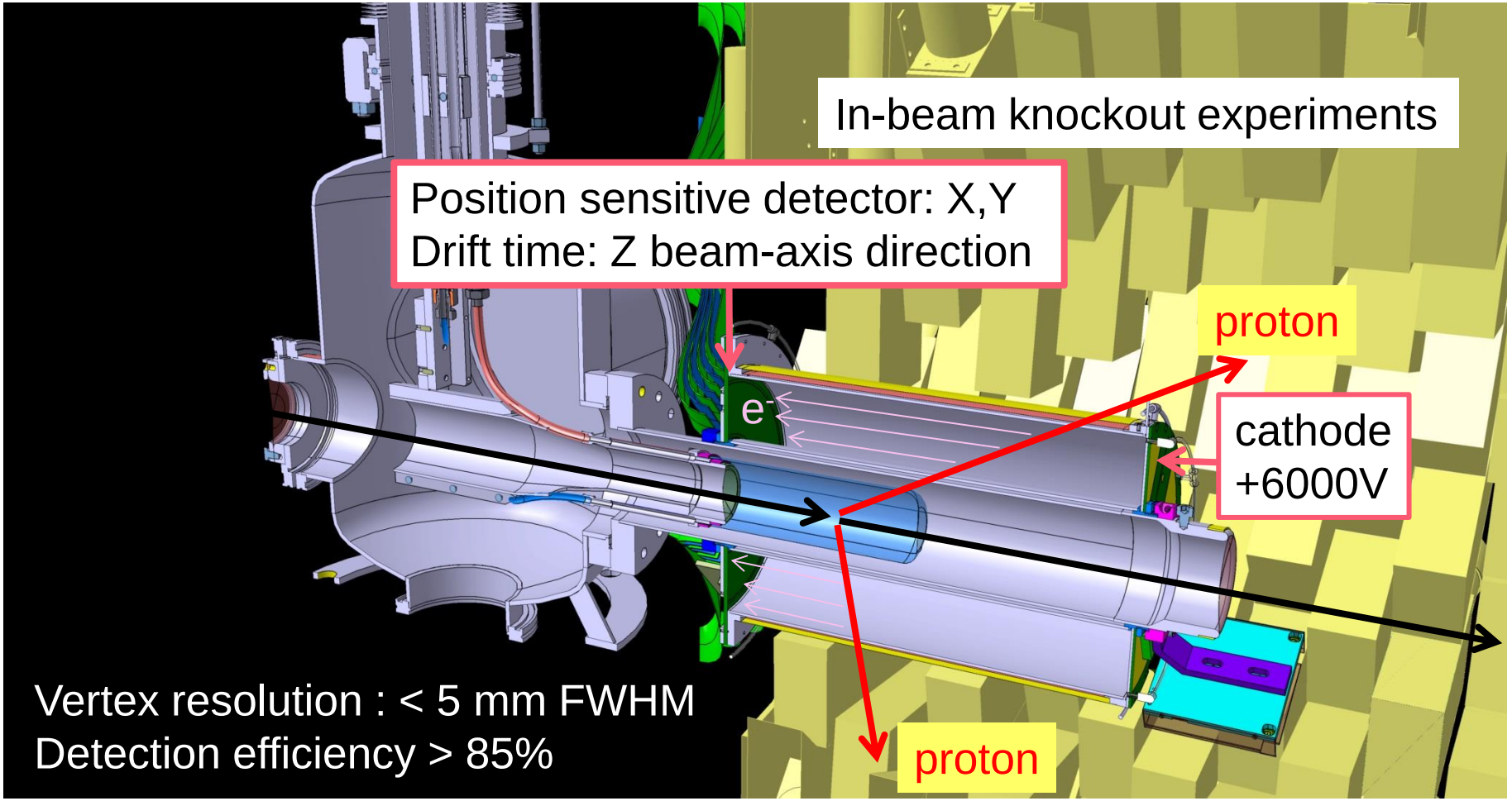


A. Obertelli *et al.,* Eur. Phys. Jour. A **50**, 8 (2014)

http://minos.cea.fr

Hosted in the Spin-Isospin Laboratory at the RIKEN Nishina Center (**T. Uesaka**' s lab)

MINOS : Magic Numbers Off Stability



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

http://minos.cea.fr

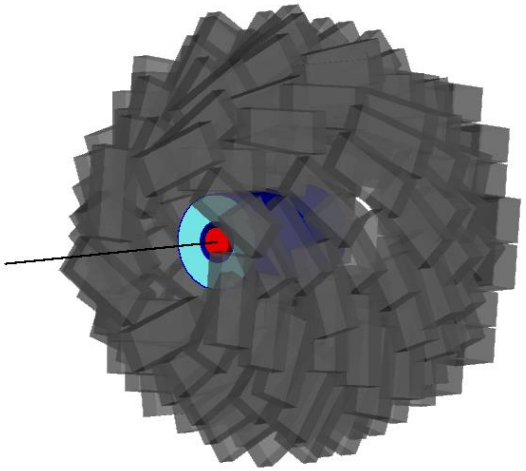
Hosted in the Spin-Isospin Laboratory at the RIKEN Nishina Center (**T. Uesaka**' s lab)

Improving luminosity, resolution and sensitivity

- Higher **luminosity** (150 cm H_2 = 1 g.cm^{-2} = 4. 10^{23} cm^{-2})
- Improved **energy resolution :** cancelation of the target contribution
- **Quasifree** *(p,2p)* or *(p,pn):* "clean" probe
  See talk by A. Bonaccorso
- Access to **intrinsic momentum distributions** despite thick target (to be proved)
- Minimized **background** (pure H_2 target, less bremsstrahlung/neutrons)

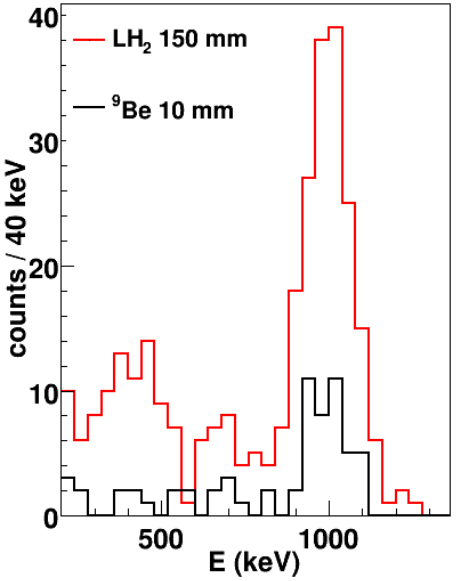
Doppler correction $E = E_\gamma \dfrac{(1 - \beta \cos\theta)}{\sqrt{1-\beta^2}}$

DALI2 γ array

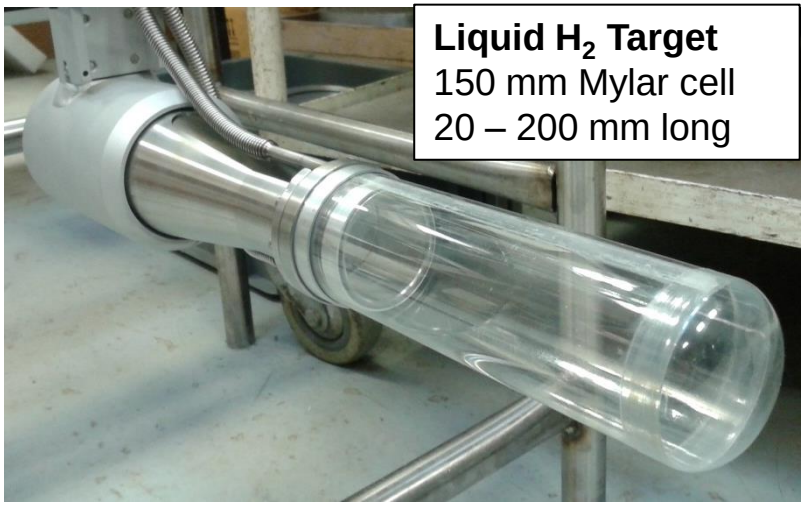


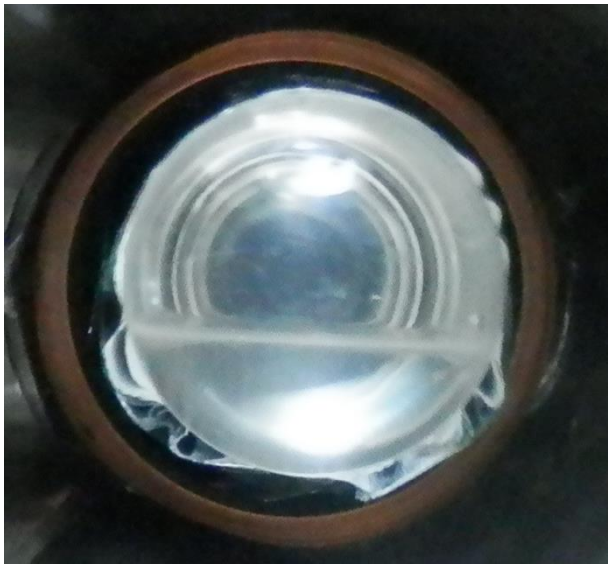
Geant4 simulation

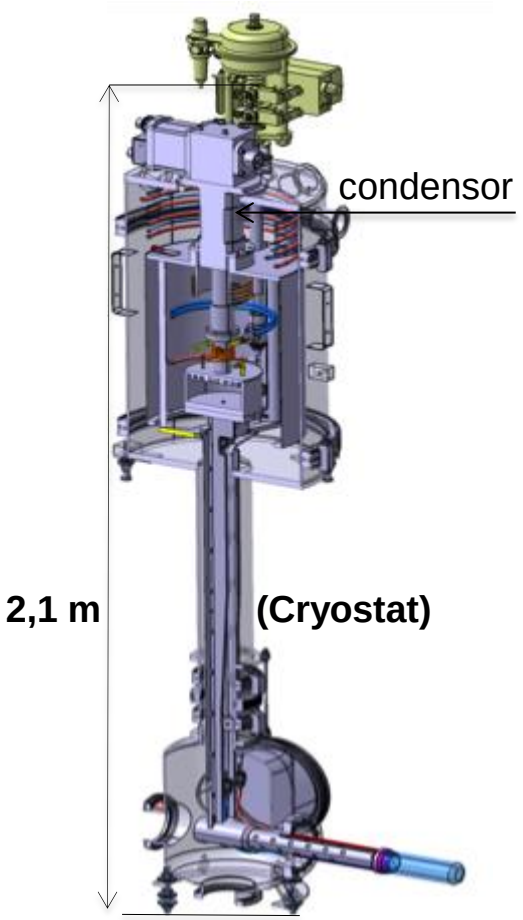
^{53}K(p,2p)^{52}Ar @ 250 MeV/nucleon



MINOS : hydrogen target







AO and T. Uesaka, EPJA **47**, 105 (2011)
C. Louchart *et al.,* NIM A **736**, 81 (2014)

MINOS: time projection chamber

Features

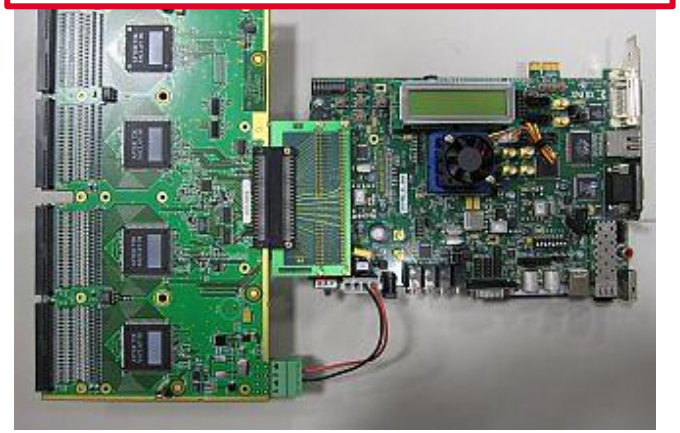
- 30 cm long / 15 cm diameter
- very low material budget
- Ar(85%)CF4(12%)iso(3%) gas:
  drift velocity: 4.5 cm/μs
  dispersion: 200 μm × √cm
- AGET: digital, 512 time bin, 100 MHz
  individual discriminator / channel
  typical dead time of 150 μs / event

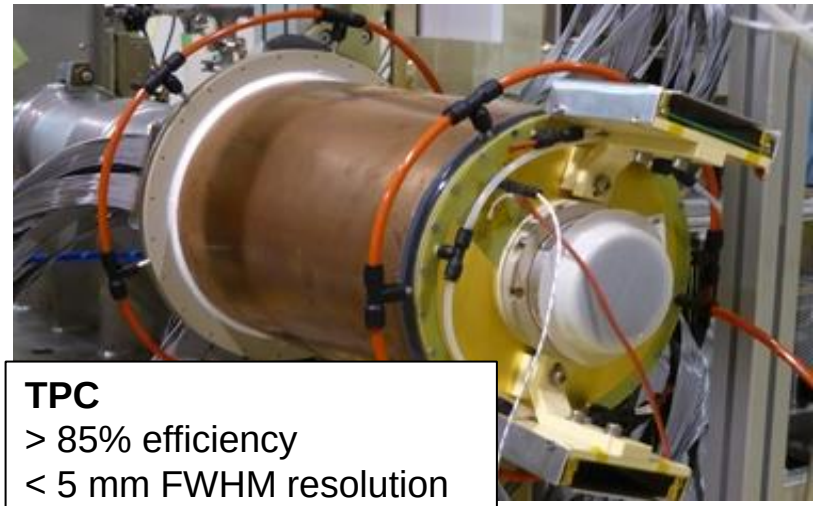
High granularity detector (TPC)

> 4000 pads, size ~4 mm^2

MicroMegas (IRFU)

New Electronics and Soft





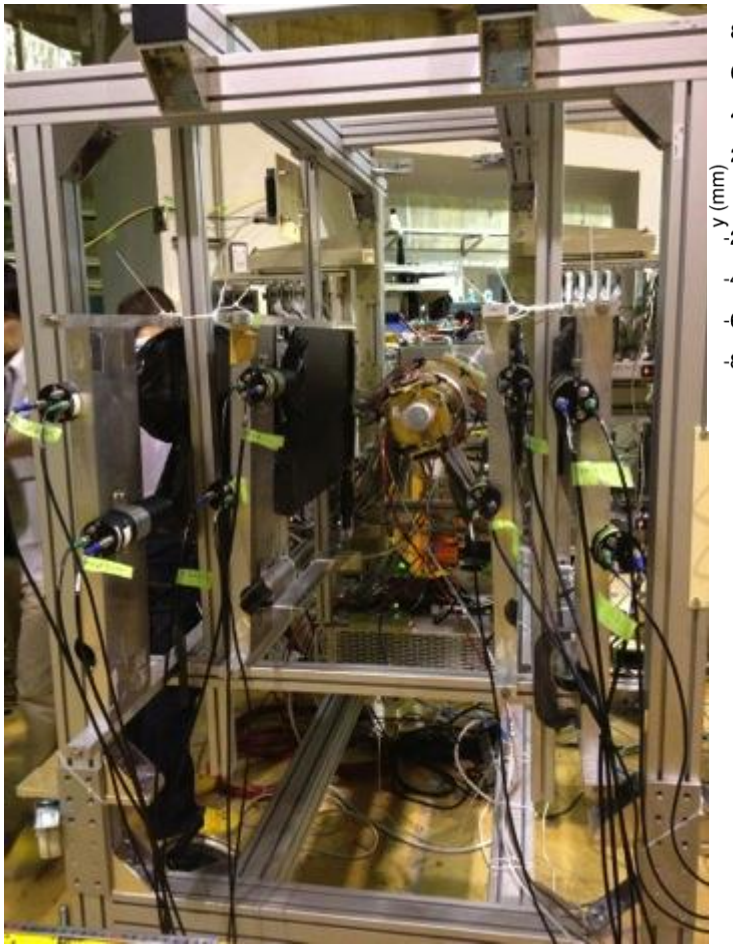
TPC
> 85% efficiency
< 5 mm FWHM resolution

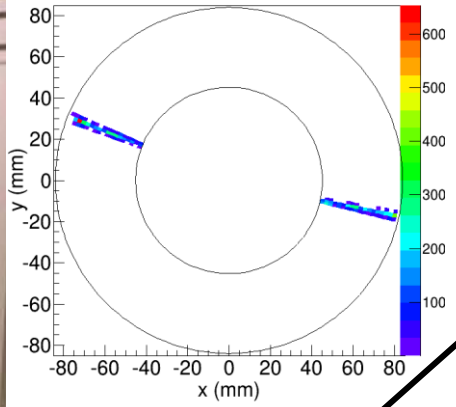
First use of **AGET chip** in a physics experiment (GET project: CEA, IN2P3, NSCL collaboration)

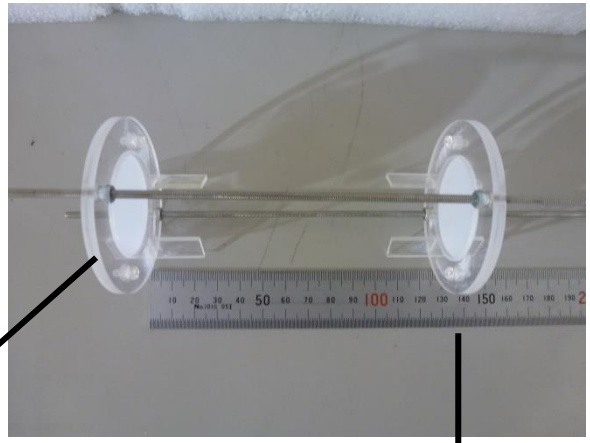
In-beam validation

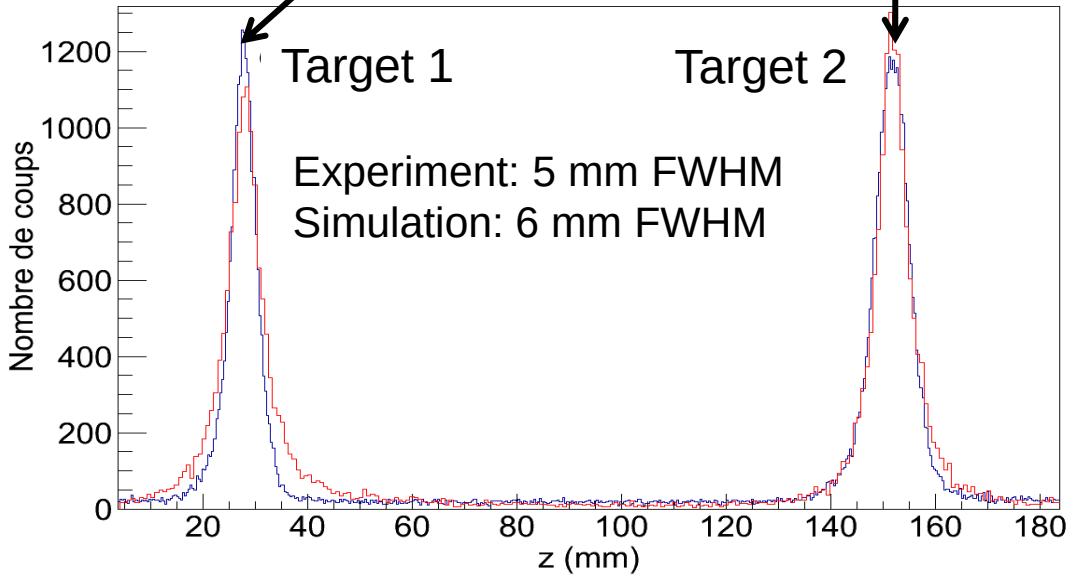
HIMAC in October 2013

He + CH2 @ 200 MeV/nucleon









MINOS tracking and TPC performances: poster by **C. Santamaria** PS2-C022

Physics program with MINOS

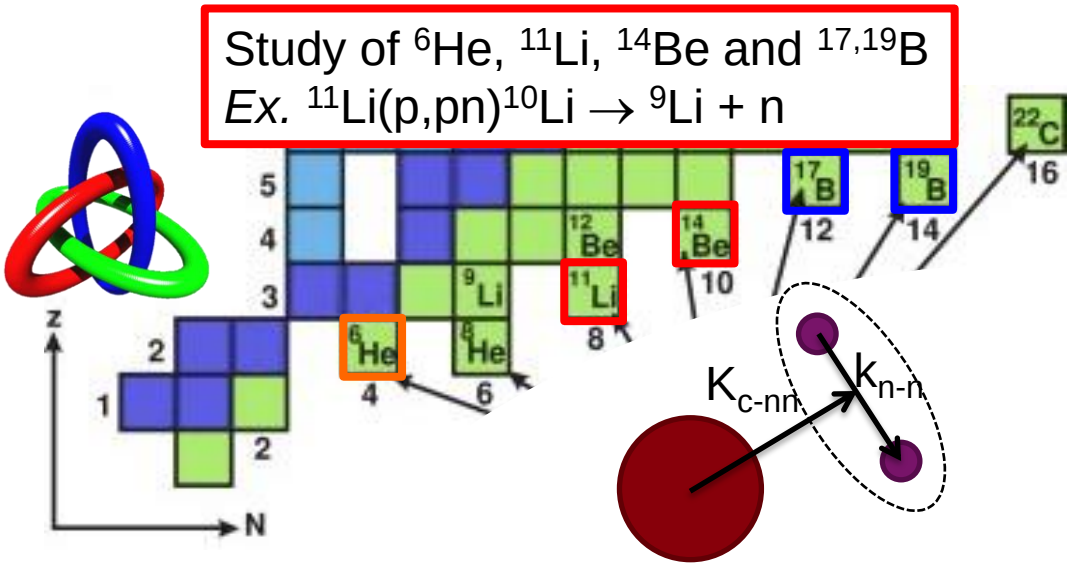
1) Origin of **di-neutron correlations** in halo nuclei

2) **Three-body forces** and continuum : binding energy of Oxygen isotopes

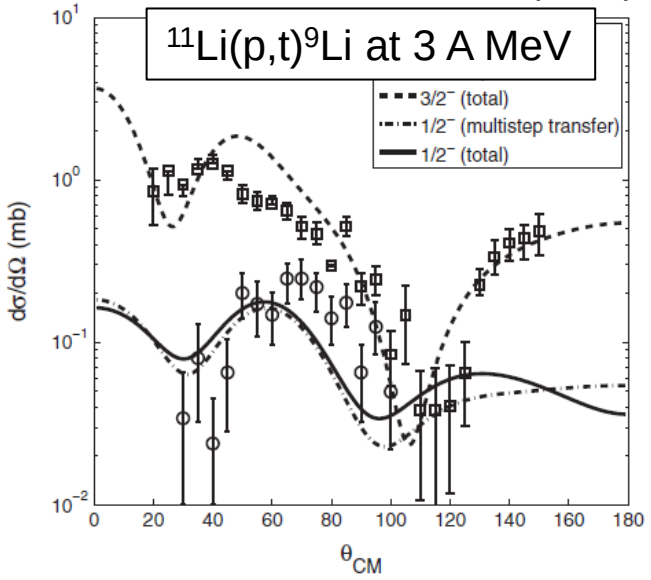
3) **Shell evolution** and search for 2_1^+ states in neutron rich nuclei (SEASTAR)

Origin of di-neutron correlations in Halo nuclei

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



I. Tanihata *et al.,* PRL **100**, 192502 (2008)
G. Potel *et al.,* PRL **105**, 172502 (2010)



A unique program to understand **Neutron Halos**:

- **multipole decomposition** from *(p,pn)*
- **minimized Final State Interactions**
- **core excitations** (γ detection)

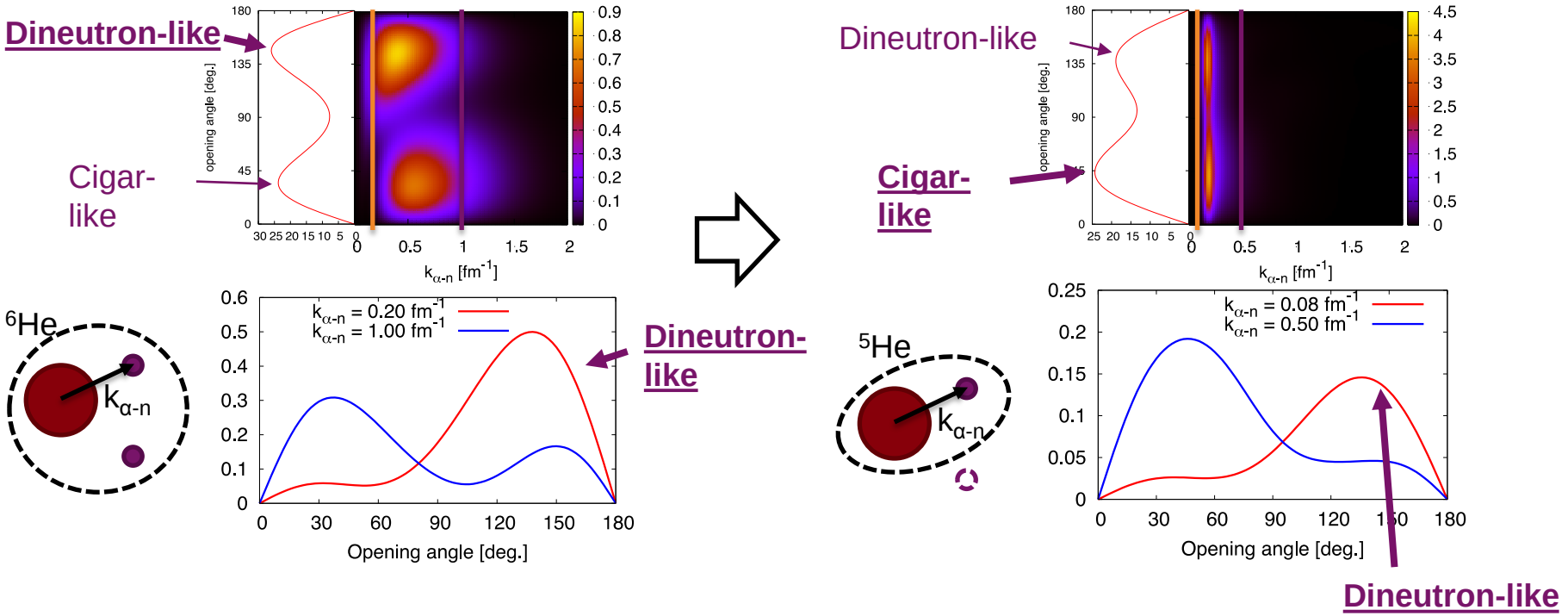
MINOS and RIBF beams **high luminosity** (×100 gain in statistics) required:

- Exclusive measurement: p,2n,gamma, heavy-ion (**4 and 5-fold coincidence**)
- Large momentum transfer for low FSI: **low cross section**

Final State Interactions: case of ^{6}He

Ground-state (non-observable)

Asymptotic cross-section (observable)

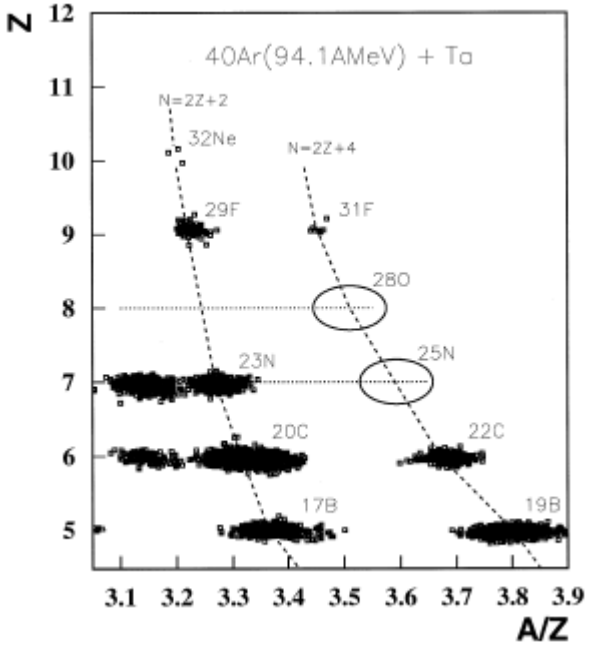


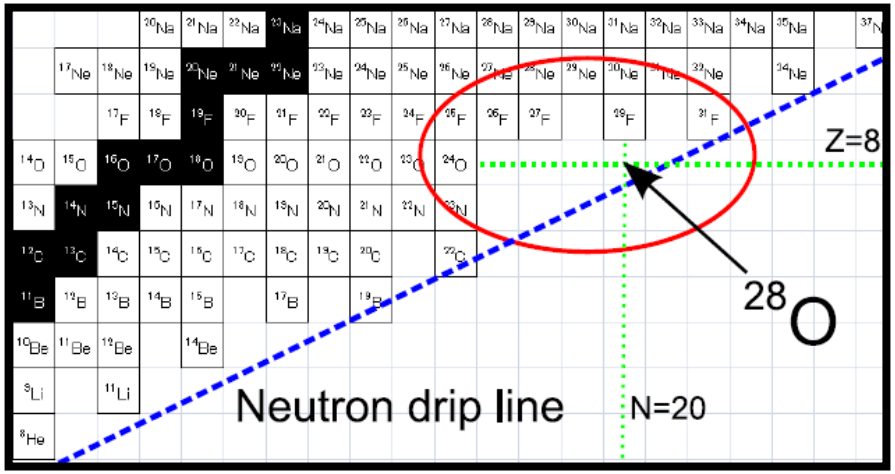
$\Rightarrow$ need for differential cross sections

Preliminary work by Y. Kikuchi (RIKEN) and K. Ogata (RCNP)

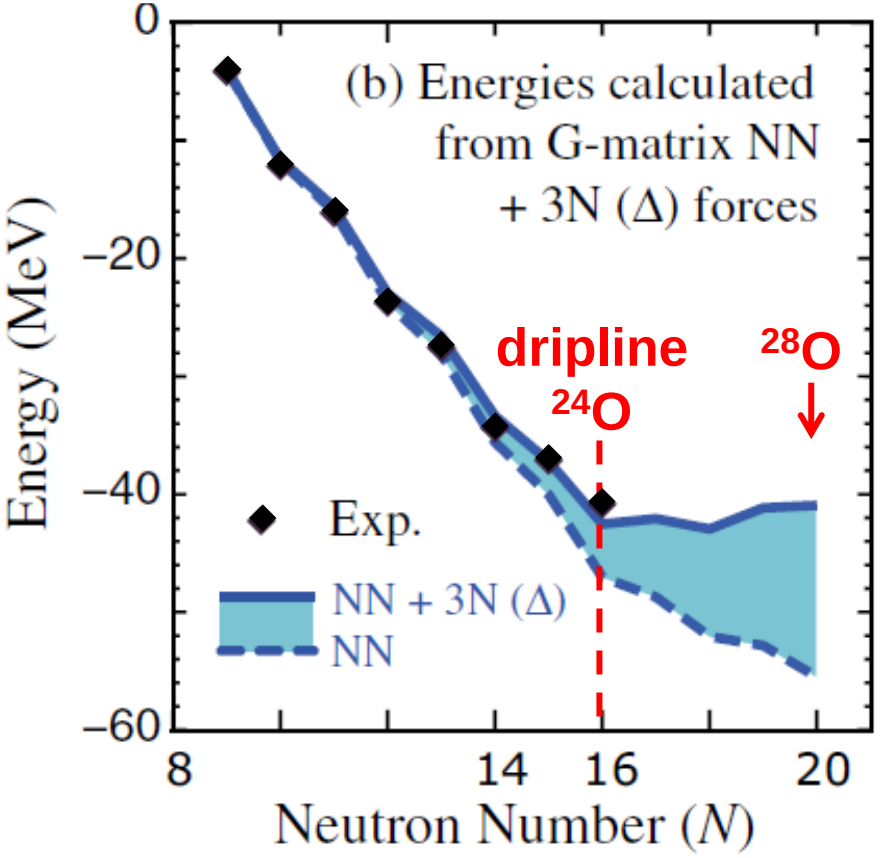
Spectroscopy of unbound Oxygen isotopes

H. Sakurai *et al.,* PLB **448**, 180 (1999)





Benchmark for three-nucleon force studies
Talk by **A. Schwenk**



T. Otsuka *et al.,* PRL **105**, 032501 (2010)
G. Hagen *et al.,* PRC **80**, 021306(R) (2009)
A. Cipollone *et al.,* PRL **111**, 062501 (2013)
H. Hergert *et al.,* PRL **110**, 242501 (2013)

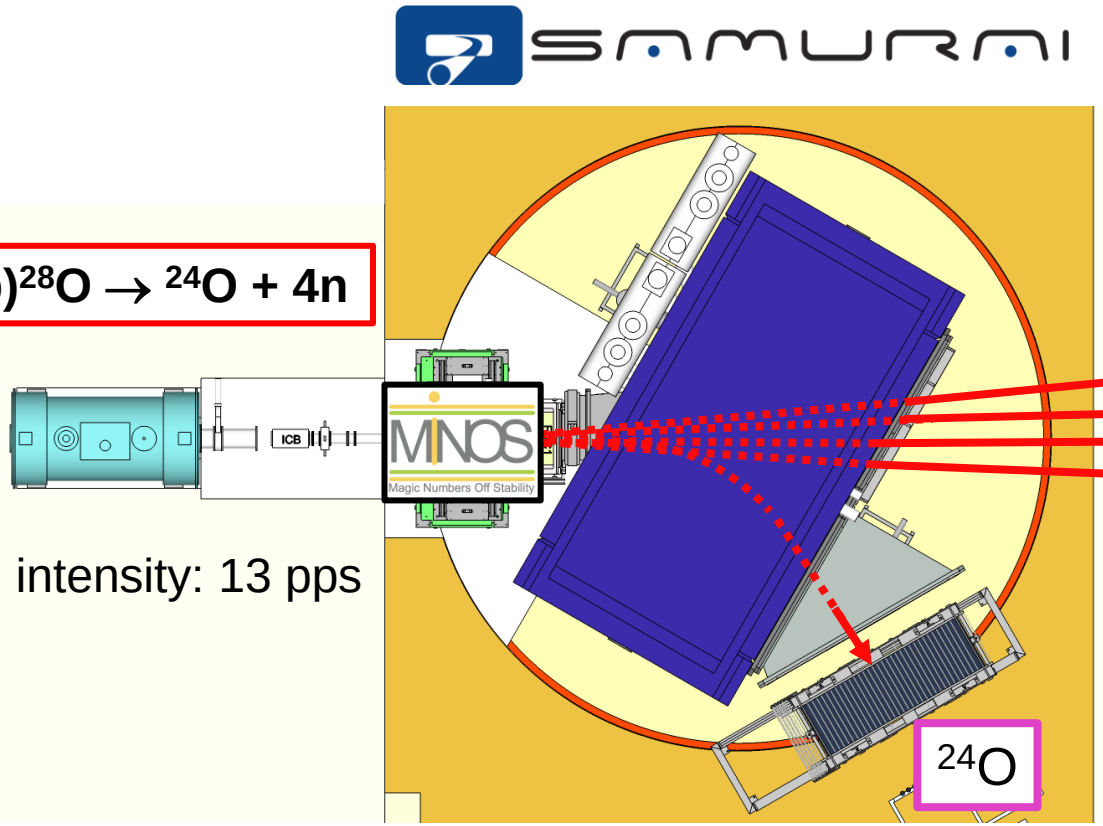
Spectroscopy of unbound Oxygen isotopes

Spokesperson: Y. Kondo, Tokyo Institute of Technology

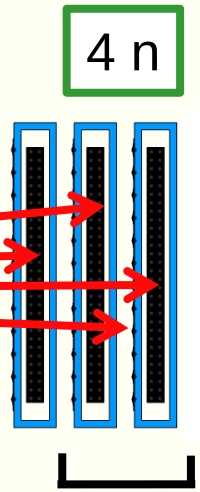
Invariant mass
Talk by **Y. Kondo**

$^{29}F(p,2p)^{28}O \rightarrow {}^{24}O + 4n$

Expected intensity: 13 pps



ε_{4n} = 0.8%
for E_{decay} = 4 MeV
with 3 detection layers



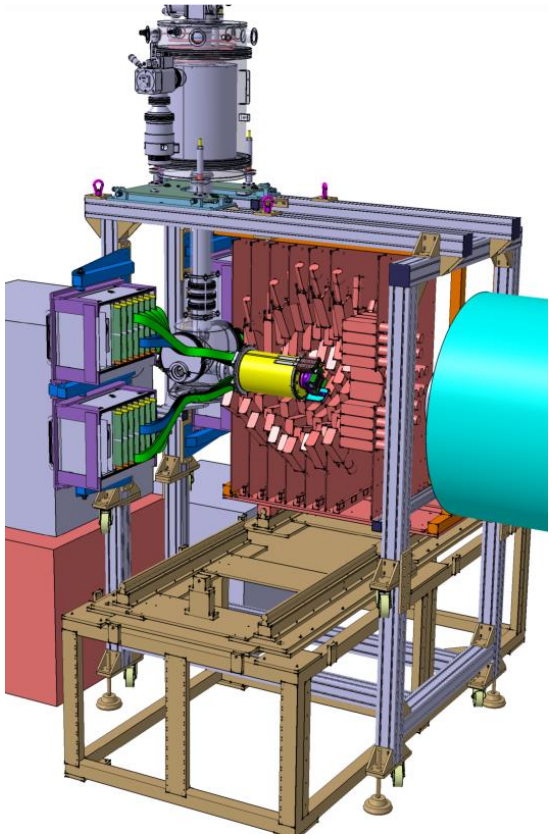
NEBULA (2 layers)

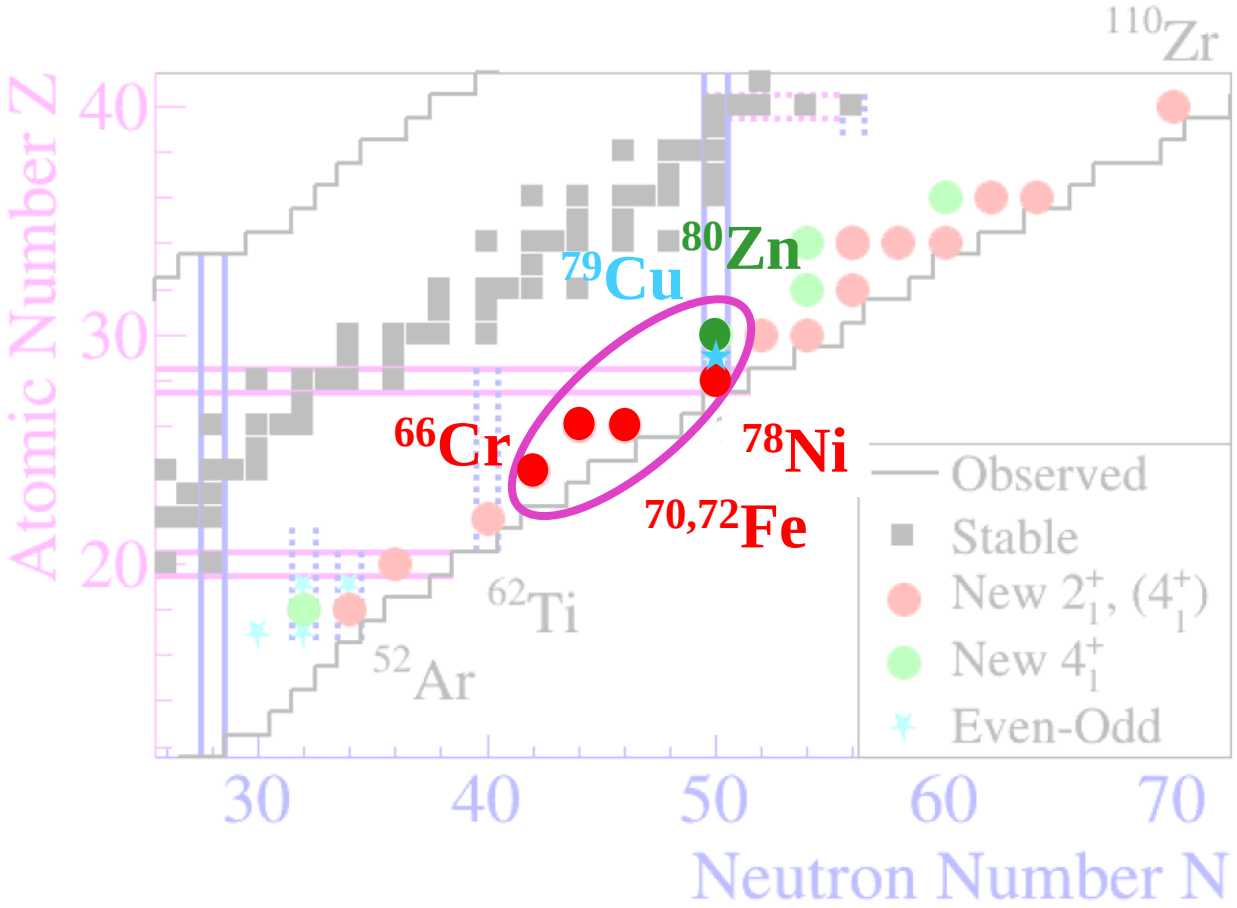
NeuLAND (1 layer)
from 2015

MINOS **thick H2 target**: high luminosity!
Vertex tracking: improve decay energy resolution.

Shell Evolution and Search for Two-plus Energies At the RIBF (SEASTAR) – a RIKEN Physics program

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





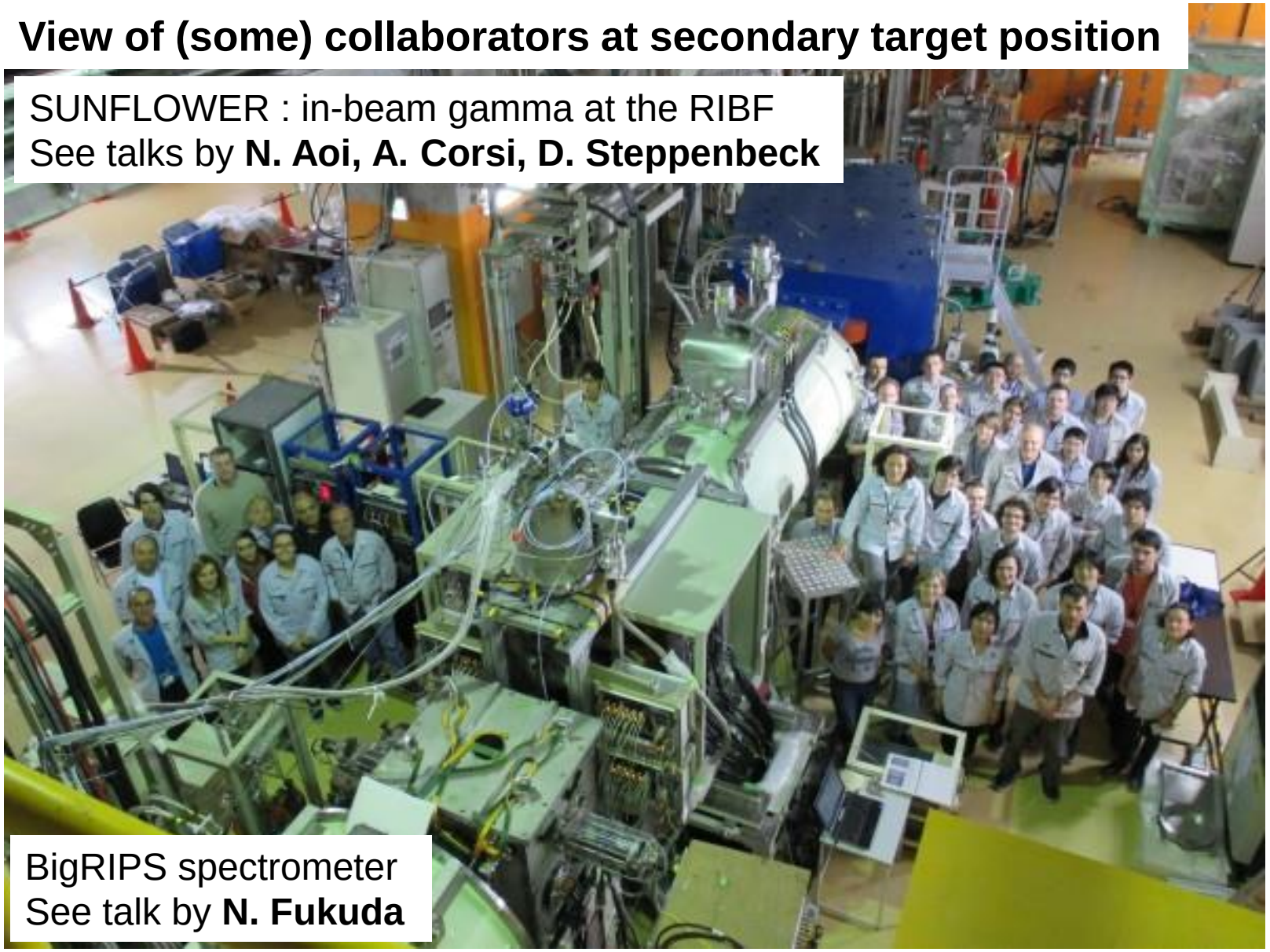
PSP framework promoted by **H. Sakurai** (RIKEN, Univ. of Tokyo)

You are welcome to the SEASTAR collaboration!

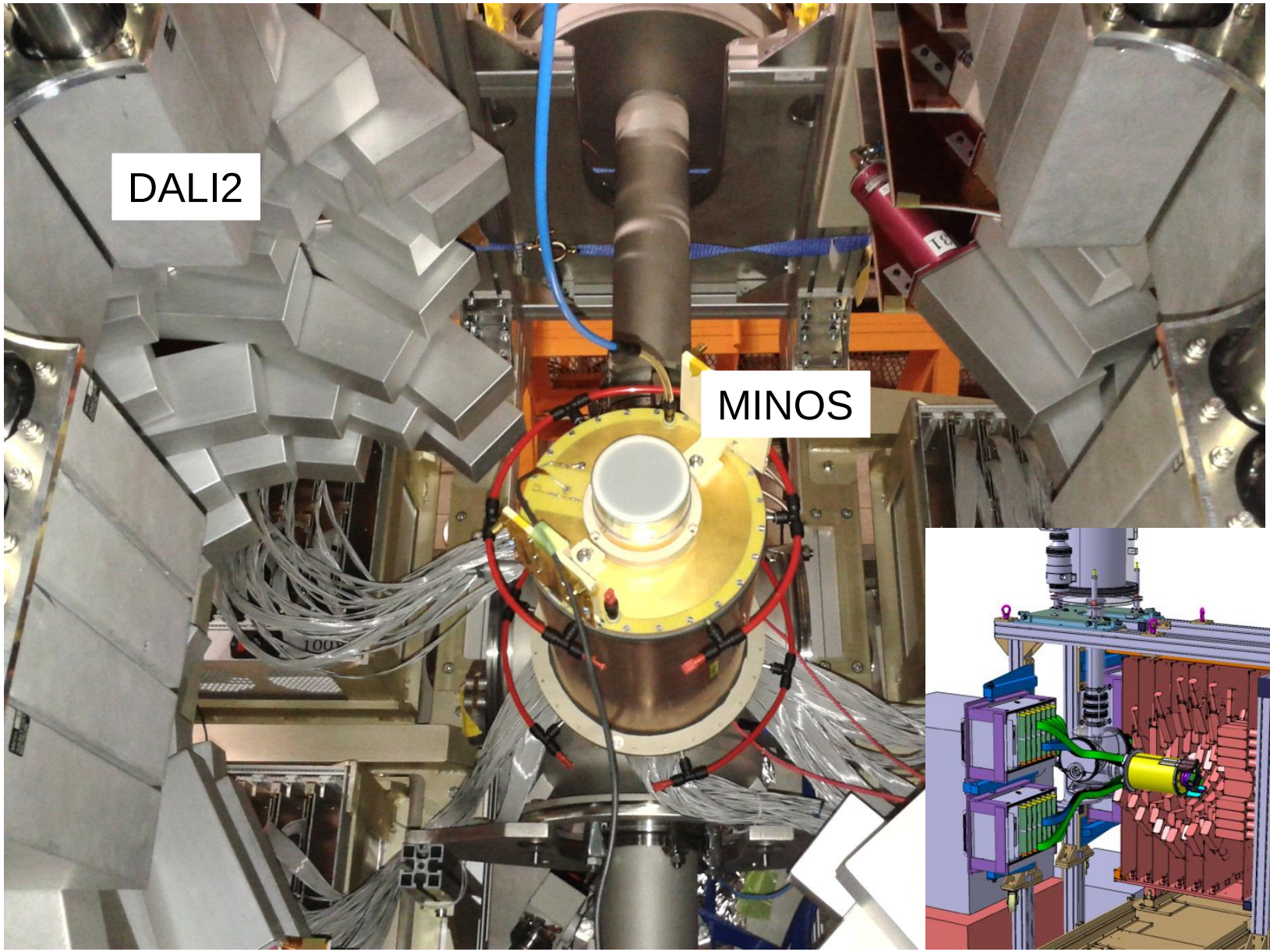
http://www.nishina.riken.jp/collaboration/SUNFLOWER/experiment/seastar/index.html

First SEASTAR campaign, may 2014

View of (some) collaborators at secondary target position

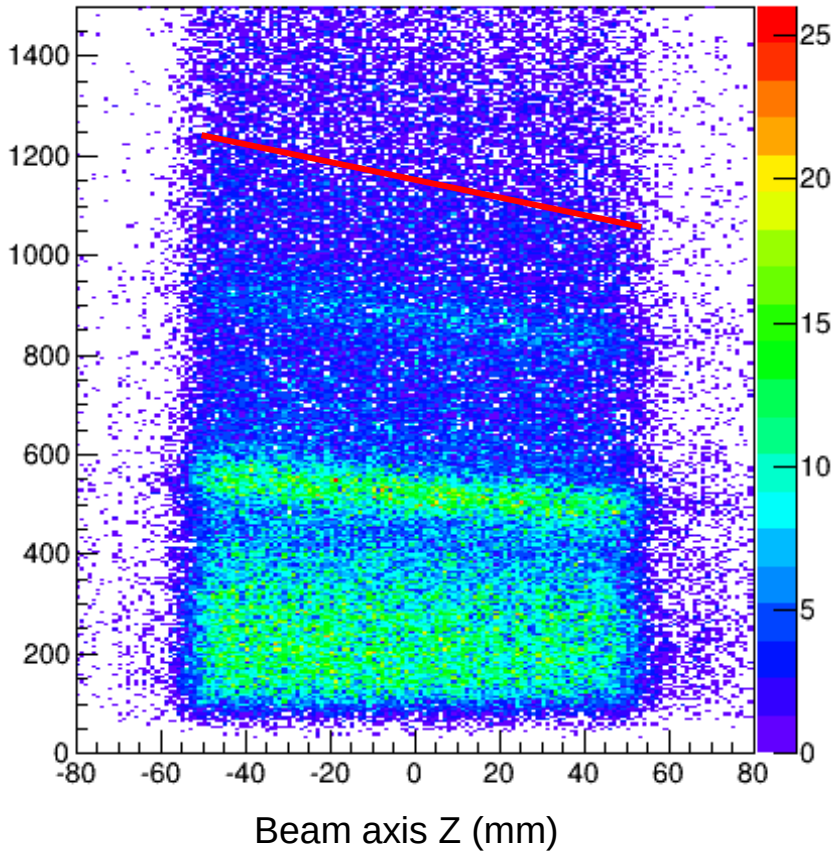


DALI2-MINOS setup

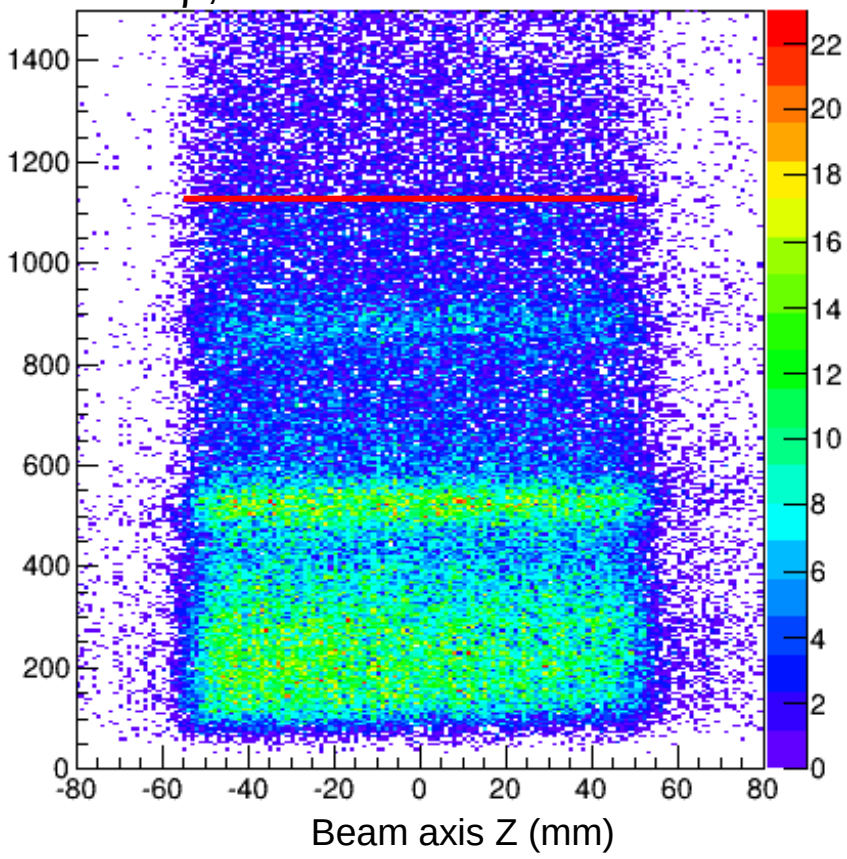


^{69}Co(p,2p)^{68}Fe @ 200 MeV/u: proof of principle

fixed β, fixed vertex



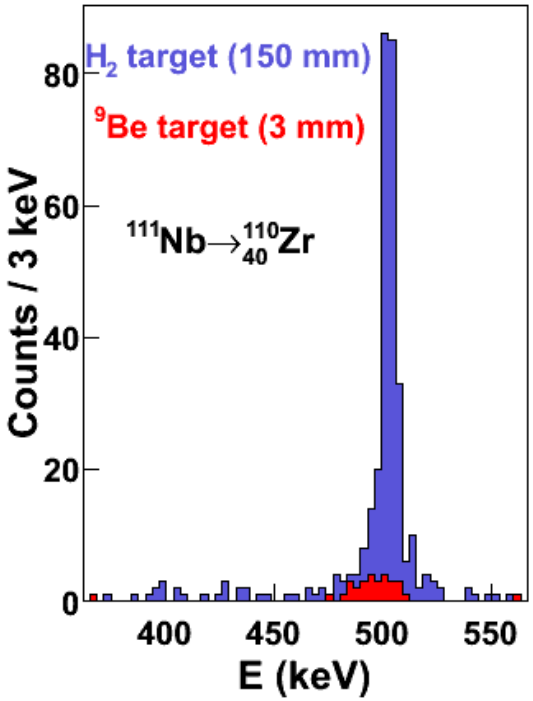
β, vertex from MINOS



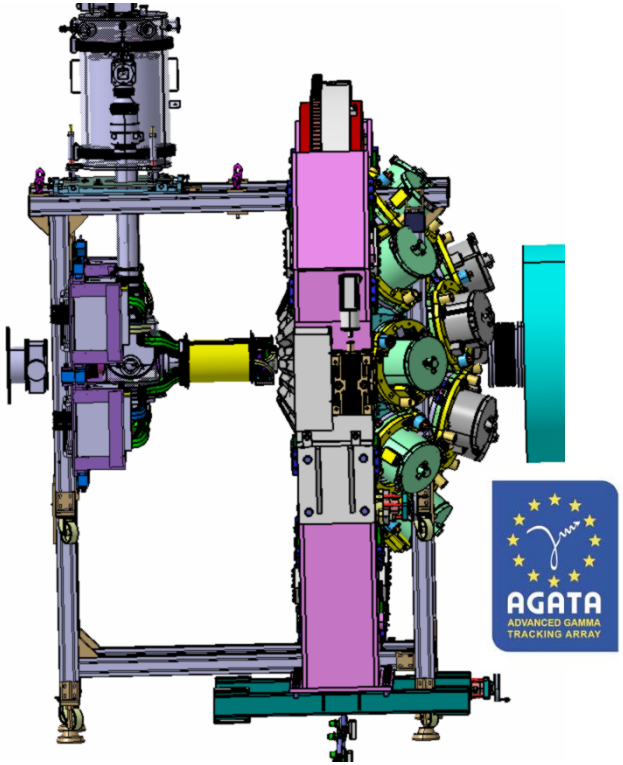
Successful SEASTAR campaign.
physics results for **^{66}Cr, ^{72}Fe, ^{78}Ni** and others available soon!

AGATA - GRETINA at the RIBF: a possible exciting physics program with MINOS

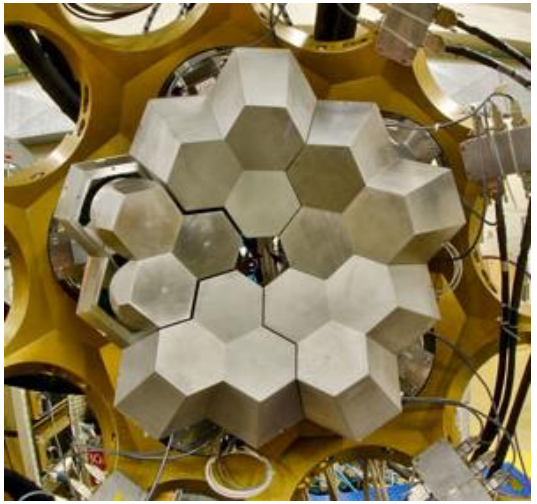
Ultimate use of new HPGe γ arrays with MINOS for in-beam γ spectroscopy:
(++) High resolution (<15 keV at 1 MeV), (++) High luminosity,
(++) High efficiency and peak over total ratio



Simulation at 300 MeV/u
With 10 AGATA TC



GRETINA with fast beams
Talk by **A. Gade**



AGATA
Talk by **D. Mengoni**

Summary

- MINOS is a **new detector** to be used at the RIKEN **RIBF**
  Thick liquid hydrogen target and vertex tracker. **First of its kind**.

- **Unique advantages**:
  1) High luminosity
  2) Improved resolution
  3) Clean reaction probe for knockout

An **exciting physics program at the RIBF** has started:

- Origin of **di-neutron correlations** in halo nuclei
- **Three-body forces** and continuum : binding energy of Oxygen isotopes
- **Shell evolution** and search for 2^+ states in neutron rich nuclei (SEASTAR)
  -- First spectroscopy of ^{66}Cr, ^{72}Fe and ^{78}Ni recently measured –

http://minos.cea.fr

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, 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 H. Baba, D. Beaumel, P. Doornenbal, M. Dozono, T. Isobe, Y. Kikuchi, T. Motobayashi, H. Otsu, M. Sasano, H. Sato, Y. Shimizu, S. Takeuchi, T. Uesaka, K. Yoneda, J. Zenihiro (*RIKEN Nishina Center)*, **A. Corsi**, A. Gillibert, A. Obertelli, E. C. Pollacco, C. Santamaria (*CEA Saclay),* S. Kawase, M. Kobayashi, M. Matsushita, S. Ota, M. Takaki, T. L. Tang, H. Tokieda, K. Yako *(CNS),* K. Kisamori, **Y. Kubota**, C. S. Lee (*CNS and RIKEN Nishina Center),* K. Kobayashi (*Rikkyo University),* T. Kobayashi (*Tohoku University),* Y. Kondo, T. Nakamura, Y. Togano (*Tokyo Institute of Technology),* K. Ogata (RCNP)

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