Inelastic scattering of Ni and Zn isotopes off a proton target

Martha Liliana Cortés Sua

Technische Universität Darmstadt

INPC 2016. Adelaide, Australia
September 11-16, 2016

Outline

Proton inelastic scattering

- Electromagnetic probe: Study of charge
- Hadronic probe: Study of charge and matter
- Matrix elements → transition densities

$$M_p^2 = B(E2;\ 0^+_{\mathrm{gs}} \rightarrow 2^+_1)$$

- Protons inelastic scattering can probe the protons and the neutrons
- Different deformations for protons and neutrons

$$\delta = \beta R; R = 1.2A^{1/3}[\mathrm{fm}]$$

Bernstein approach

$$\frac{M_n}{M_p} = \frac{N}{Z}\left[\frac{\delta_{p,p'}}{\delta_C} + \frac{Zb_p}{Nb_n}\left(\frac{\delta_{p,p'}}{\delta_C} - 1\right)\right]$$

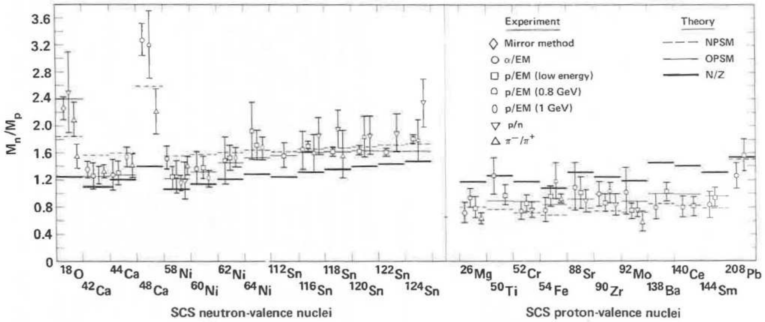
[A. M. Bernstein, V. R. Brown, and V. A. Madsen, Phys. Lett. B103, 255 (1981).]

- For a homogeneous liquid model, $M_n/M_p = N/Z$
- Two ways to measure:
  - Direct kinematics: Thin target, measure protons
  - Inverse kinematics: Thick target, γ- ray detection

$\downarrow$

Use of radioactive ion beams

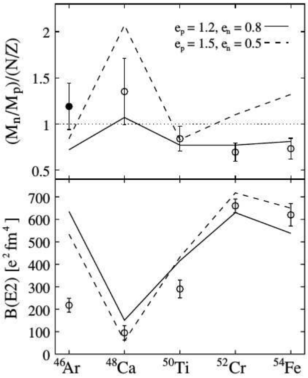
Previous results



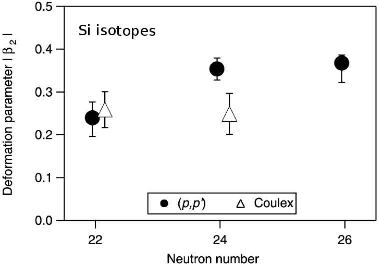
[A. M. Bernstein, V. R. Brown, and V. A. Madsen, Comments Nucl. Part. Phys. **11**, 203 (1983).]

- Systematic behavior of M_n/M_p in single closed shell nuclei
- Combining different hadronic probes gives insight in the structure

Use of RIBs



[L. A. Riley, *et al.*, Phys. Rev. C **72**, 024311 (2005).]



[C. M. Campbell, *et al.*, Phys. Lett. B **652**, 169 (2007).]

- Consistent results
- Energies up to 80 MeV/u
- Extension to more exotic nuclei

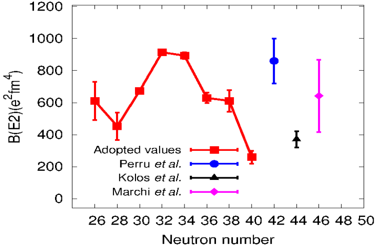
Shell evolution around $Z = 28$

For ^{74}Ni:

$$\delta_C = 0.78 \pm 0.13 \text{ fm} \qquad \delta_{p,p'} = 1.04 \pm 0.16 \text{ fm}$$

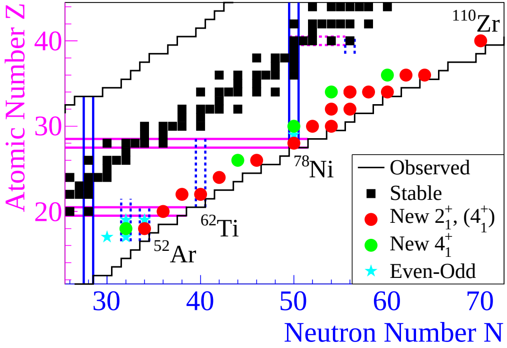
$$\frac{M_n/M_p}{N/Z} = 1.4 \pm 0.5$$

[T. Marchi, *et. al.*, PRL 113, 182501 (2014)]
[N. Aoi, *et. al.*, PLB 692, 302 (2010)]



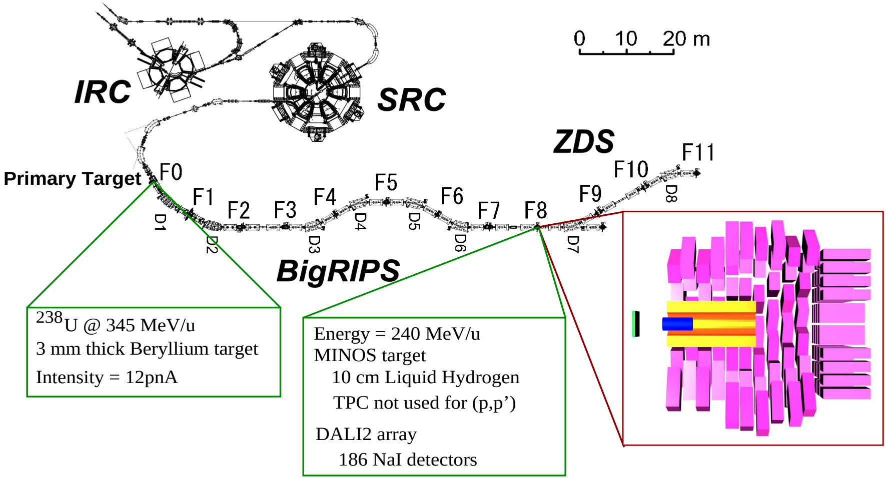
Measurement of proton inelastic scattering of ^{70,72,74}Ni and ^{76,78,80}Zn at 200 MeV/u

Shell Evolution And Search for Two-plus energies At the RIBF (SEASTAR)



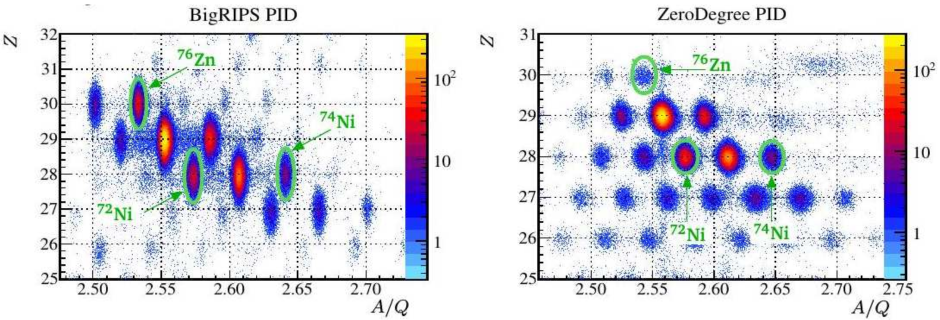
- 2^+ spectroscopy using $(p, 2p)$ and $(p, 3p)$ reactions
- 24 days for data runs, 32.5 days including BigRIPS/ZD tuning

Experimental setup



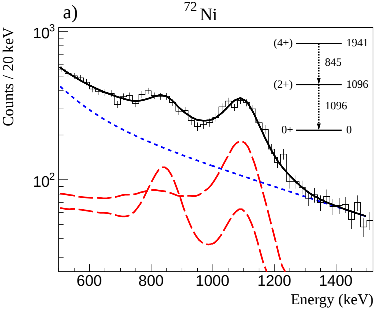
MINOS: A. Obertelli *et al.*, Eur. Phys. J. A 50, 8 (2014)
DALI: S. Takeuchi *et al.*, Nucl. Inst. Meth. A 763, 596 (2014)

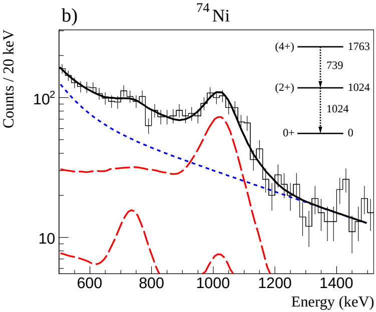
Particle identification



- Three experimental settings to measure ^{70,72,74}Ni and ^{76,78,80}Zn
- Between $10^5 - 10^7$ particles for different isotopes in ZeroDegree
- Doppler correction after particle selection and background subtraction

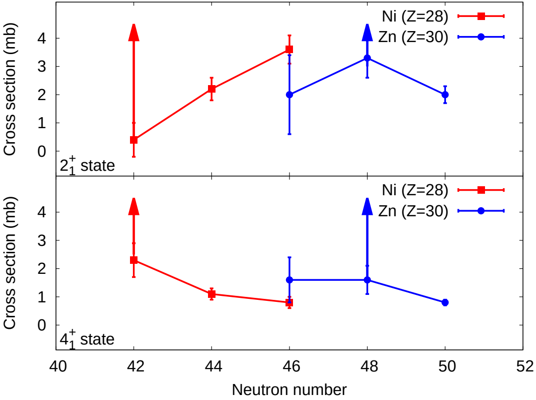
Doppler corrected spectra





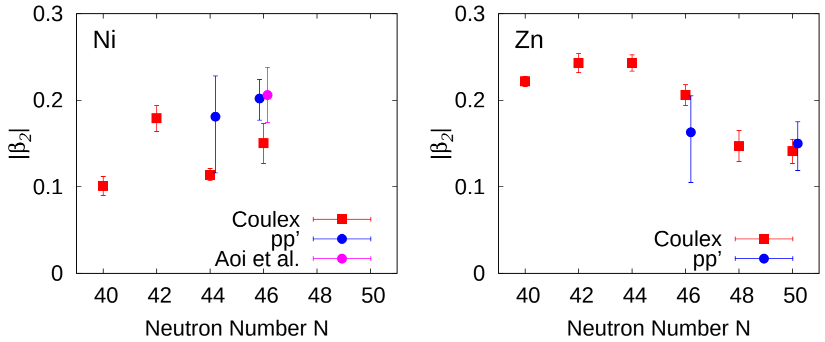
- Simulated response of DALI2 and a double-exponential fitted
- Exclusive cross section of proton inelastic scattering from the fit
- Error: 6% on DALI2 efficiency and 2% on the target thickness

Cross section and deformation length



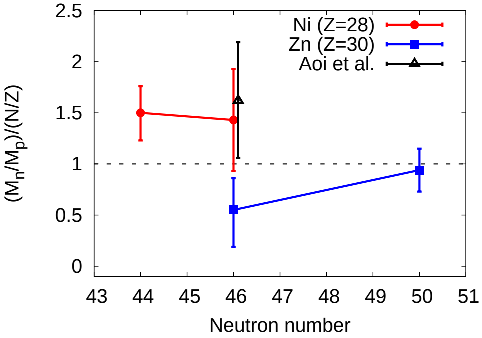
- Isomers in ^{70}Ni and ^{78}Zn: Lower limits
- Some energy dependence
- Use of DWBA to obtain deformation

Deformation parameter



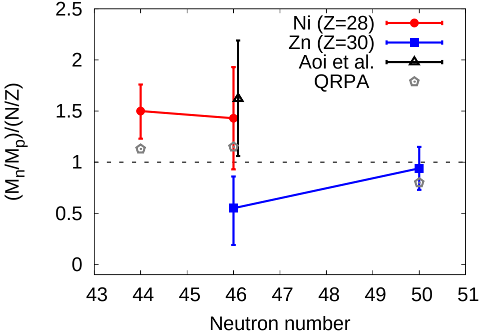
- Deformation length calculated with ECIS-97
- Use of KD02 optical potential
- Confirmation of Aoi. et al

Matrix elements ratio



- Single closed shell behavior is maintained
- Higher neutron contribution in Ni
- Method is feasible

Results



- Feasible method, but large errors
- Further theoretical approach required
- Possible future measurements:
  - Use of segmented Ge detectors

S. Péru *et al.*, Eur. Phys. J. A 50, 88 (2014)

Summary

- Proton inelastic scattering in Ni and Zn performed.
- Cross section for the first 2^+ and 4^+ states measured.
- Deformation length obtained using ECIS-97.
- Measurement at energies above 200 MeV/u.
- Contribution of neutrons to the Ni chain and of protons to the Zn chain.
- Proton inelastic scattering data available from the first two SEASTAR campaigns and further data expected from the third campaign.

SEASTAR collaboration

TU Darmstadt: M. L. Cortés, M. Lettmann, C. Louchart, N. Pietralla, V. Werner
RIKEN: H. Baba, P. Doornenbal, T. Isobe, S. Koyama, Y. Kubota, K. Matsui, T. Miyazaki, S. Momiyama, T. Motobayashi, S. Nishimura, H. Otsu, P.A. Söderström, H. Sakurai, M. Sasano, Y. Shiga, S. Takeuchi, R. Taniuchi, T. Uesaka, K. Yoneda, H. Wang, J. Wu
CEA Saclay : G. Authelet, D. Calvet, F. Château, A. Corsi, A. Delbart, J.-M. Gheller, A. Gillibert, V. Lapoux, C. Péron, A. Peyaud, E.C. Pollacco, J.-Y. Roussé
CNS: M. Matsushita, S. Ota,D. Steppenbeck
IPN Orsay: S. Franchoo, A. Gottardo, L. Olivier, I. Stefan, D. Suzuki
IPHC, Strasbourg: R. Lozeva
University of Tokyo: M. Niikura
University of Brighton: F. Browne
Institute of nuclear science, Hanoi: L.X. Chung
MTA Atomki: Zs. Dombradi, Z. Korkulu, Zs. Vajta
University of Oslo: F. Giacoppo, K. Hadynska-Klek, E. Sahin
University of Hong Kong: J. Lee, Z. Xu
University Surrey: Z. Patel, C. M. Shand
Tohoku University: T. Sumikama

Thank you!