Study of neutron-rich nuclei via heavy-ion double-charge exchange reactions

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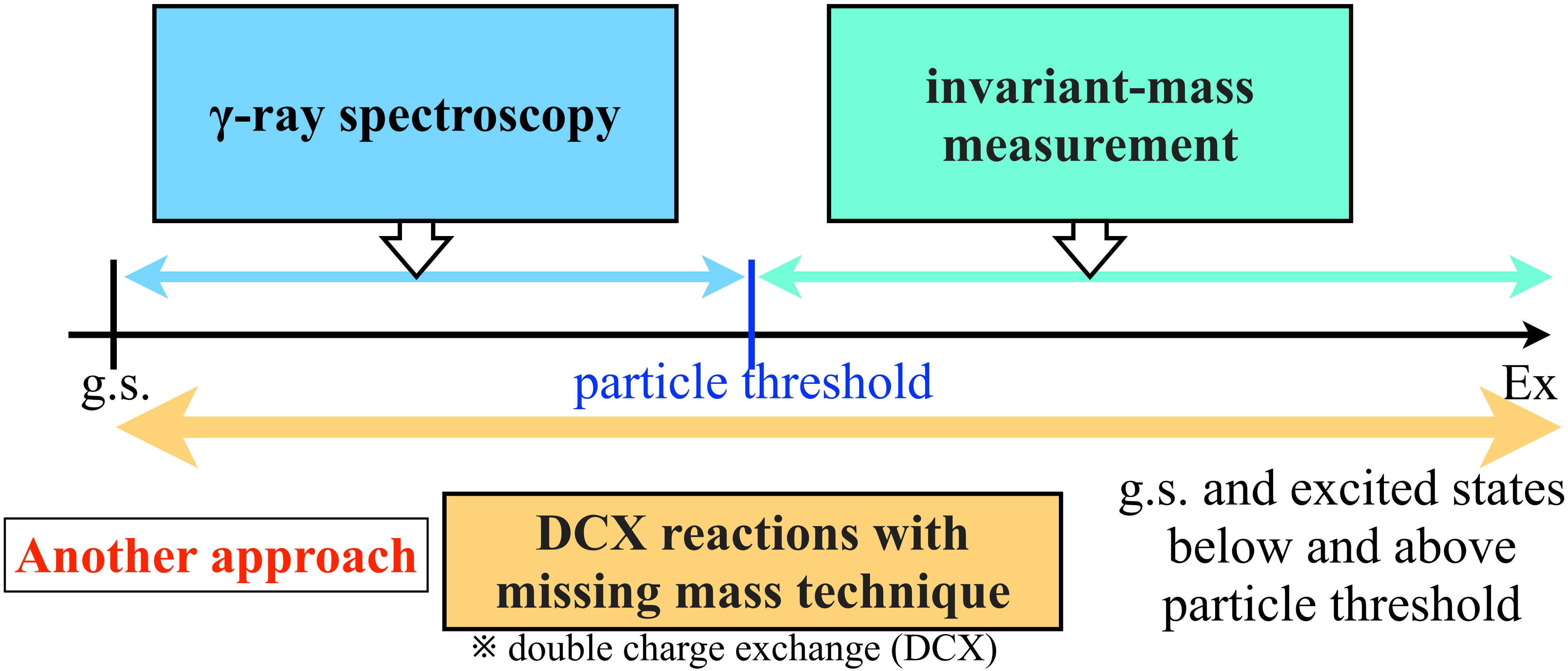
Neutron-rich nuclei

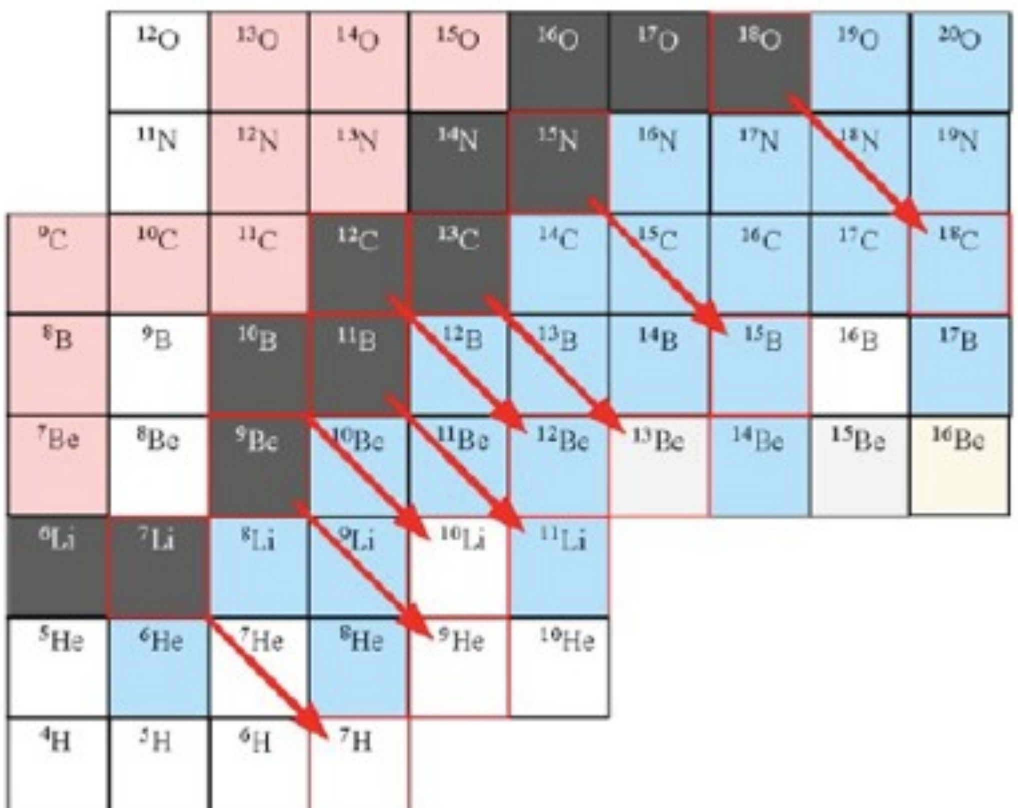
- **Exotic phenomena**
  - disappearance of conventional magic numbers
  - neutron skin and halo structures
  - intruder states
- experimental approach for neutron-rich nuclei

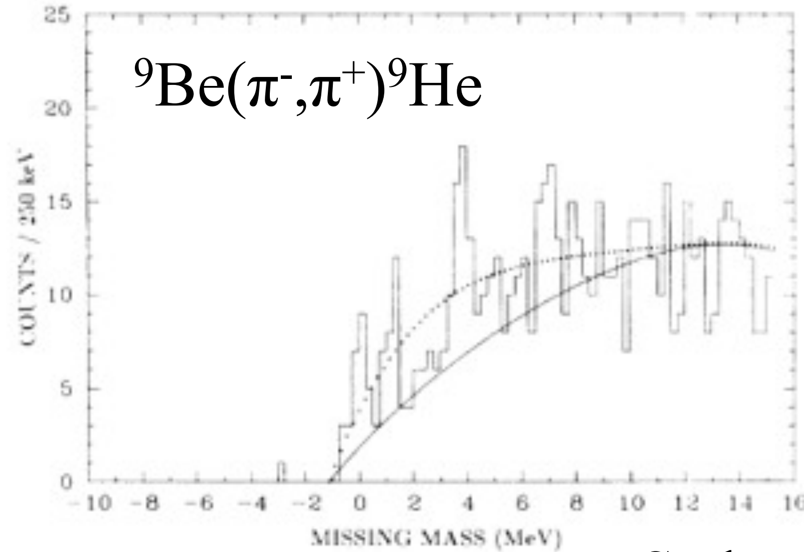


Double-Charge eXchange (DCX) reactions

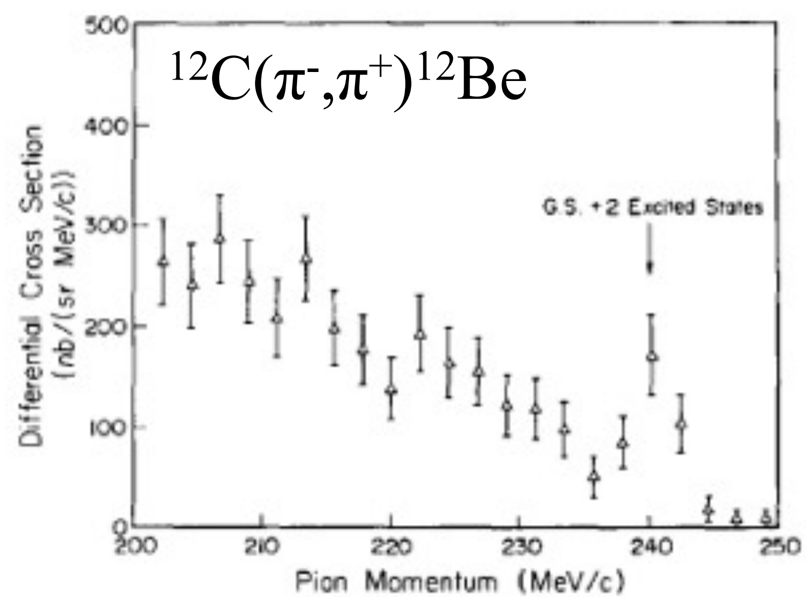
- **Another probes to neutron- or proton-rich nuclei**

- π-DCX reactions





K.K. Seth *et al.*



J.E. Ungar *et al.*

Heavy-Ion DCX (HIDCX)

HIDCX reactions can transfer spin and isospin by two units.

- Missing mass measurement

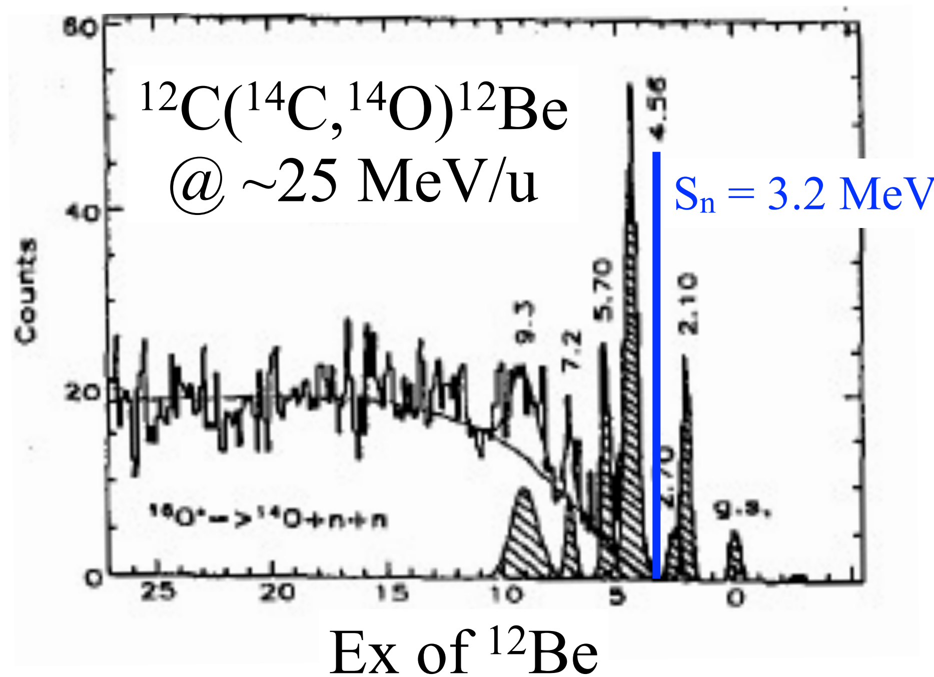
ground state

bound and/or unbound states

→ **one shot measurement**

- HIDCX at an intermediate energy
  - simple reaction process
  - angular distributions
    - sensitive to multipolarities
- As a First step

^{12}C,^{9}Be(^{18}O,^{18}Ne)^{12}Be,^{9}He



Ex of ^{12}Be

W. von Oertzen *et al.*

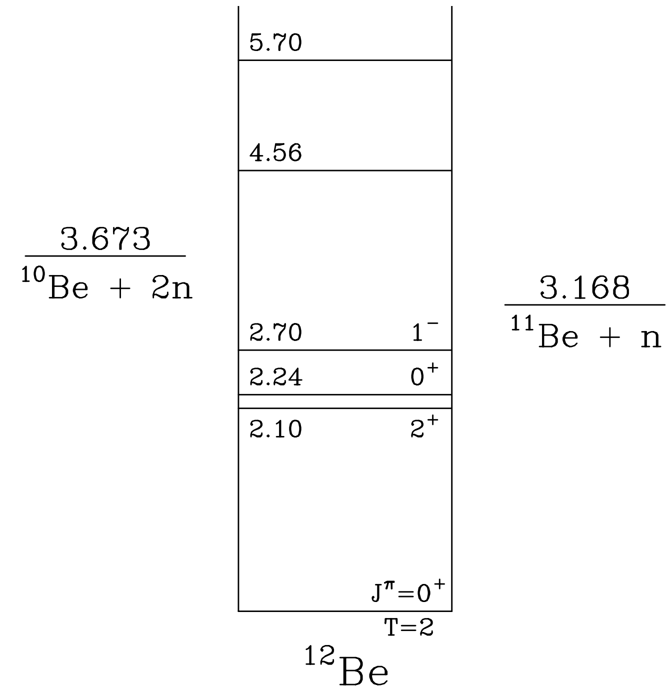
^{12}Be and ^{9}He

- The nucleus ^{12}Be

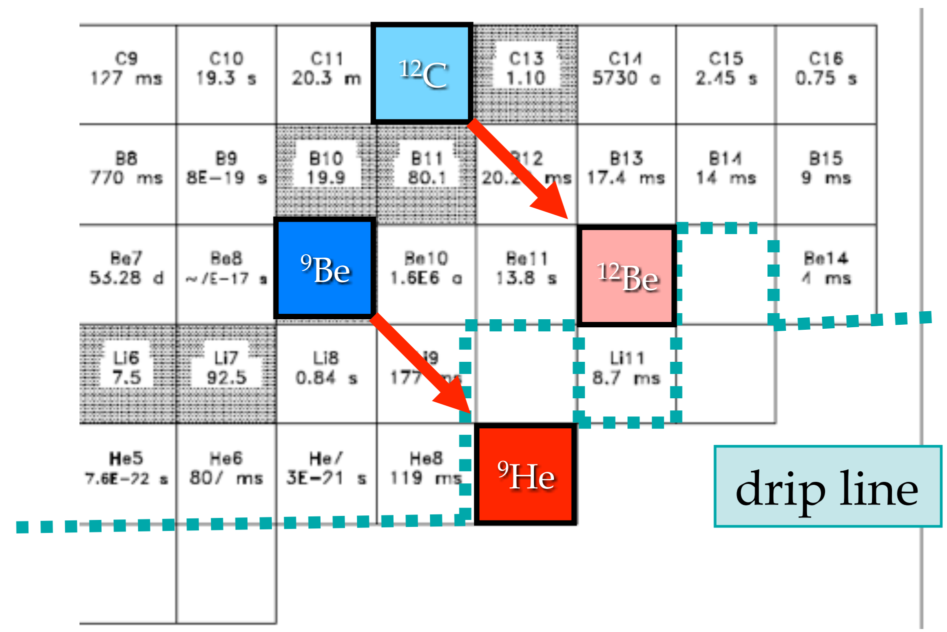
disappearance of the N=8 magicity

  - intruder 1^- state
  - low-energy isomer state

extensively studied



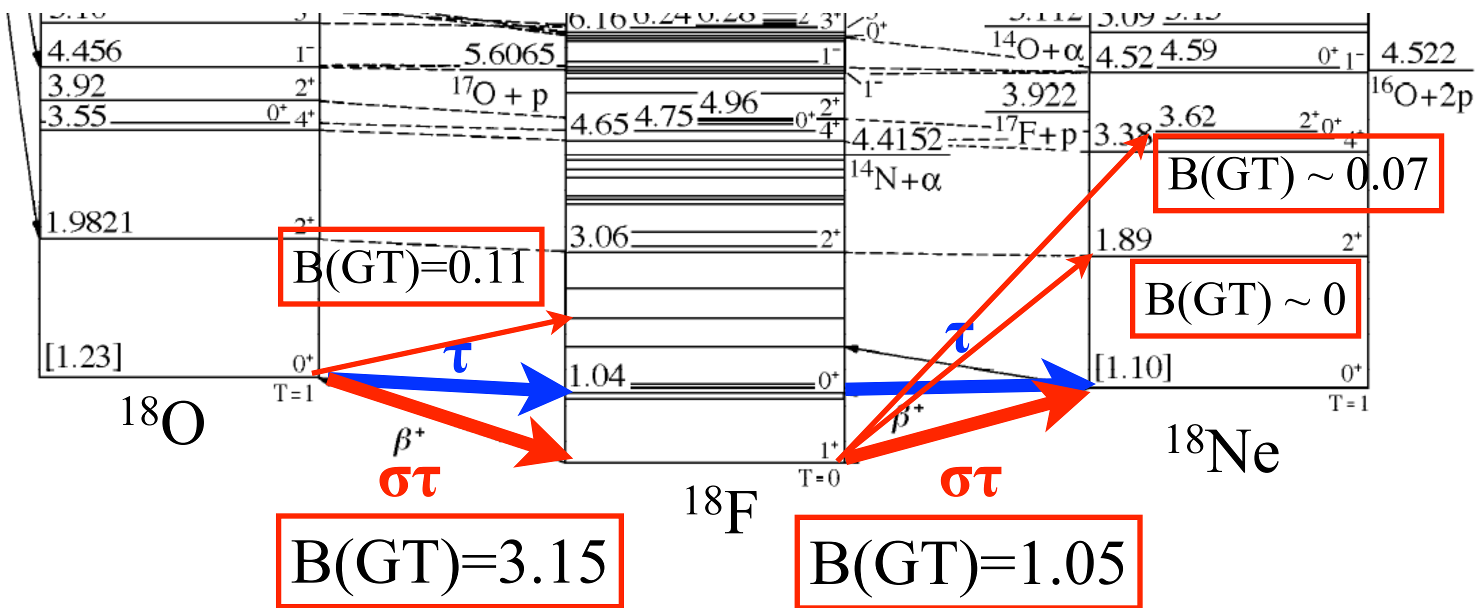
- The nucleus ^{9}He
  - **large A/Z ratio (= 4.5)**
  - unbound nucleus
  - spin-parities are not fixed



(^{18}O,^{18}Ne) reaction

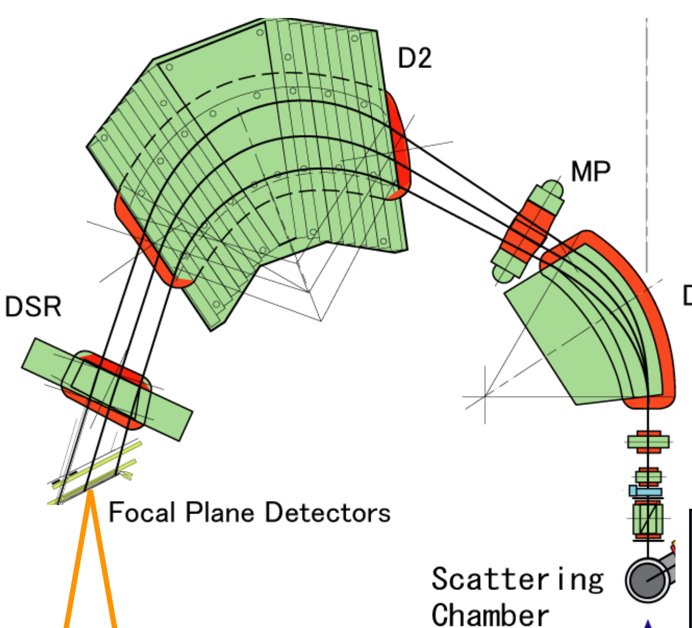
- **Ground states of ^{18}O and ^{18}Ne are among the same super-multiplet.**
  - simple transition process
  - large transition probability

- **^{18}O is a stable isotope.**
  - high intensity



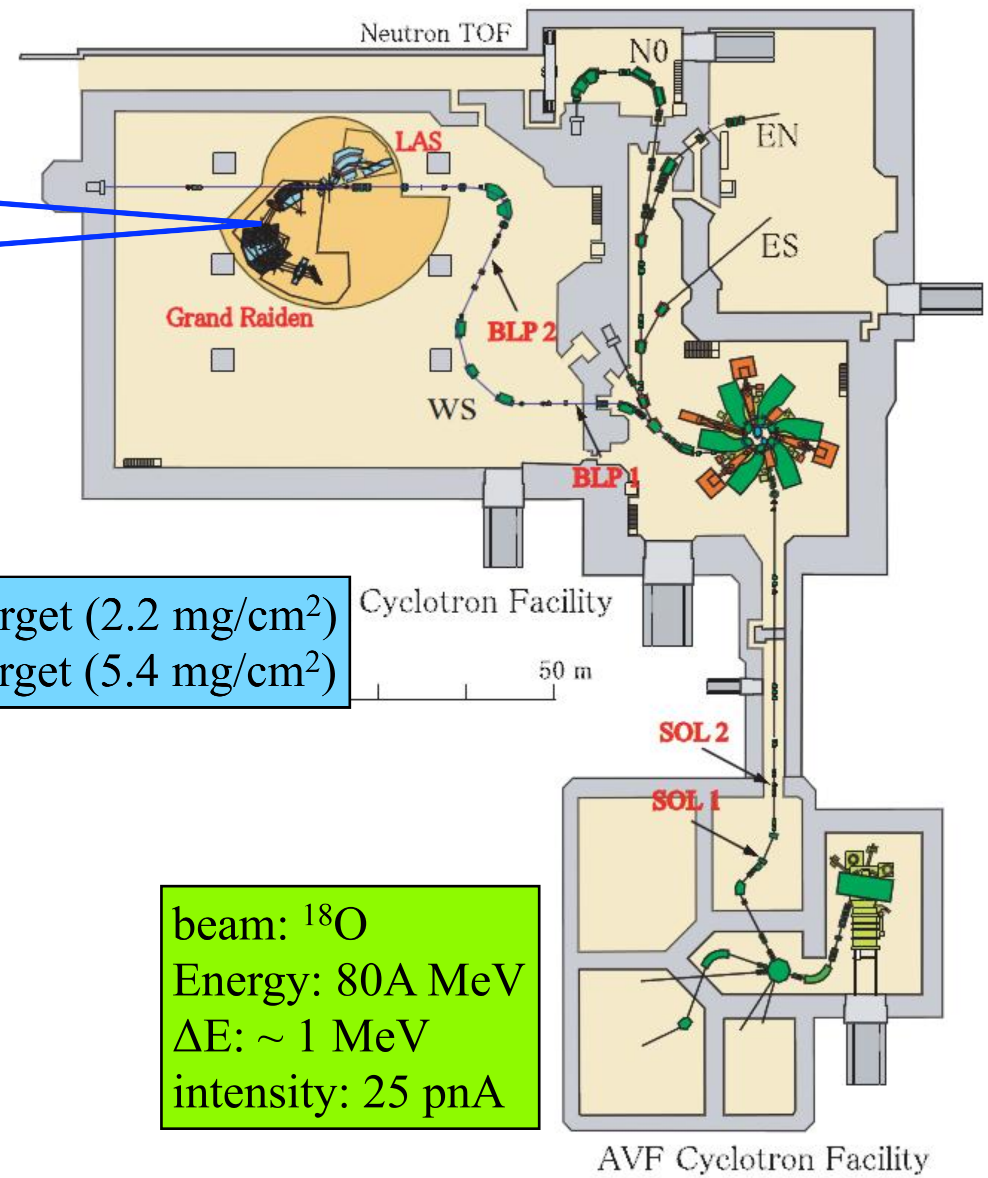
^{12}C,^{9}Be(^{18}O,^{18}Ne) experiment @ RCNP

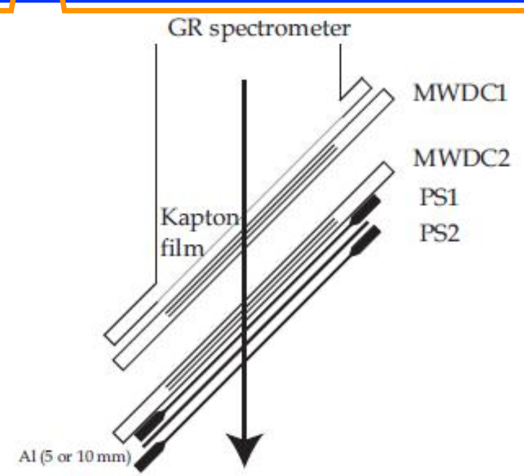
Energy resolution = 1.2 MeV
mainly due to beam energy spread



^{nat}C target (2.2 mg/cm^2)
^{9}Be target (5.4 mg/cm^2)

^{18}O beam





MWDCs and plastic scinti.

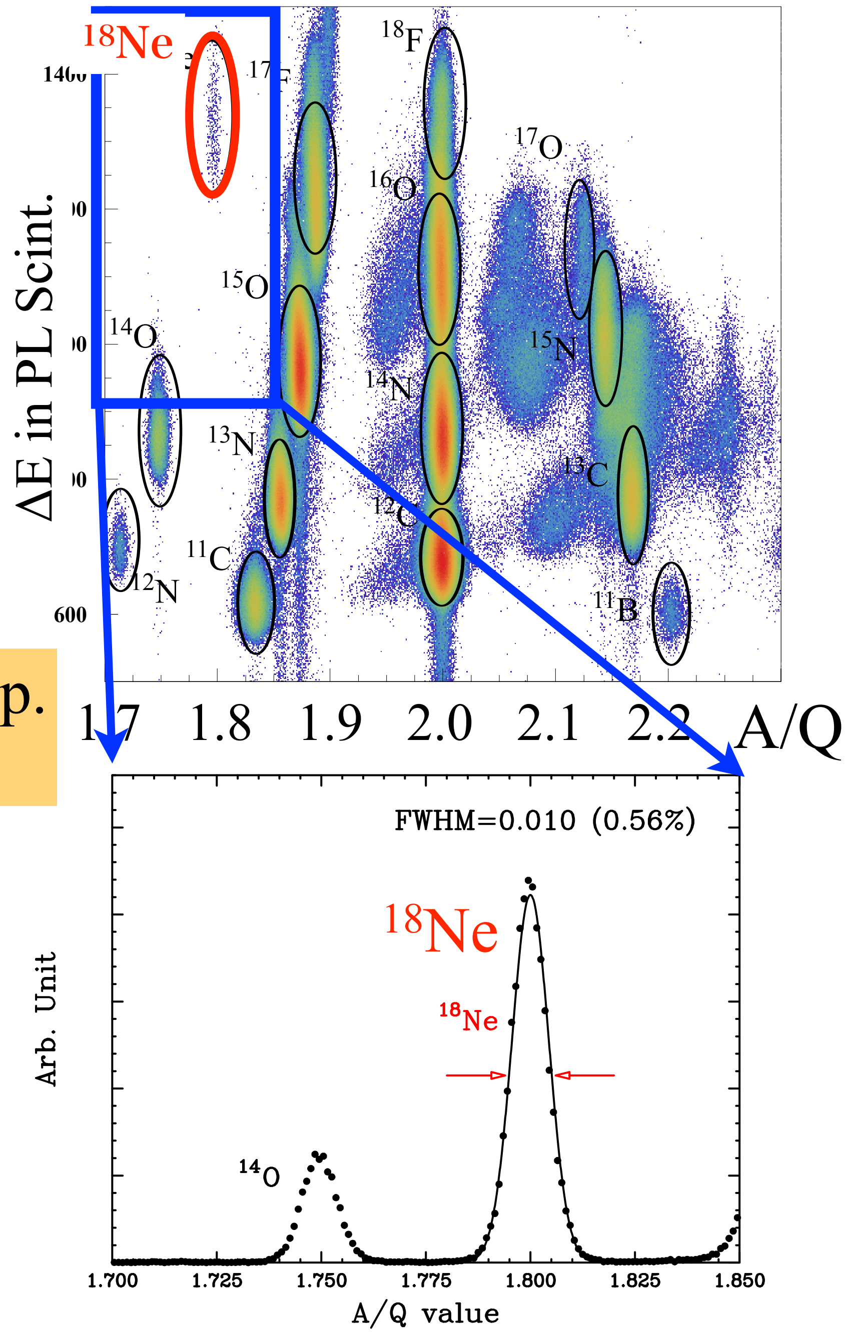
beam: ^{18}O
Energy: 80A MeV
ΔE: ~ 1 MeV
intensity: 25 pnA

Particle Identification

- PI for 18Ne was realized mainly by *A/Q* information.

$$B\rho = \frac{p}{Q} = \frac{A m_N \beta\gamma}{Q} \rightarrow \frac{A}{Q} = \frac{B\rho}{\beta\gamma m_N}$$

^{18}Ne has a unique A/Q value of 1.8 in this exp.
(^{9}B is unbound)

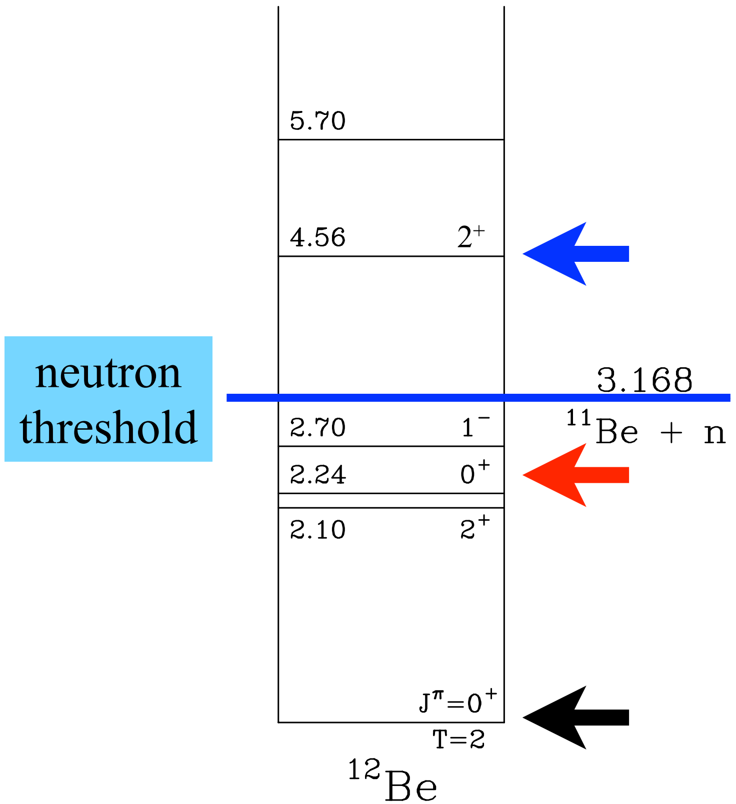


^{18}Ne was safely separated from other isotopes.

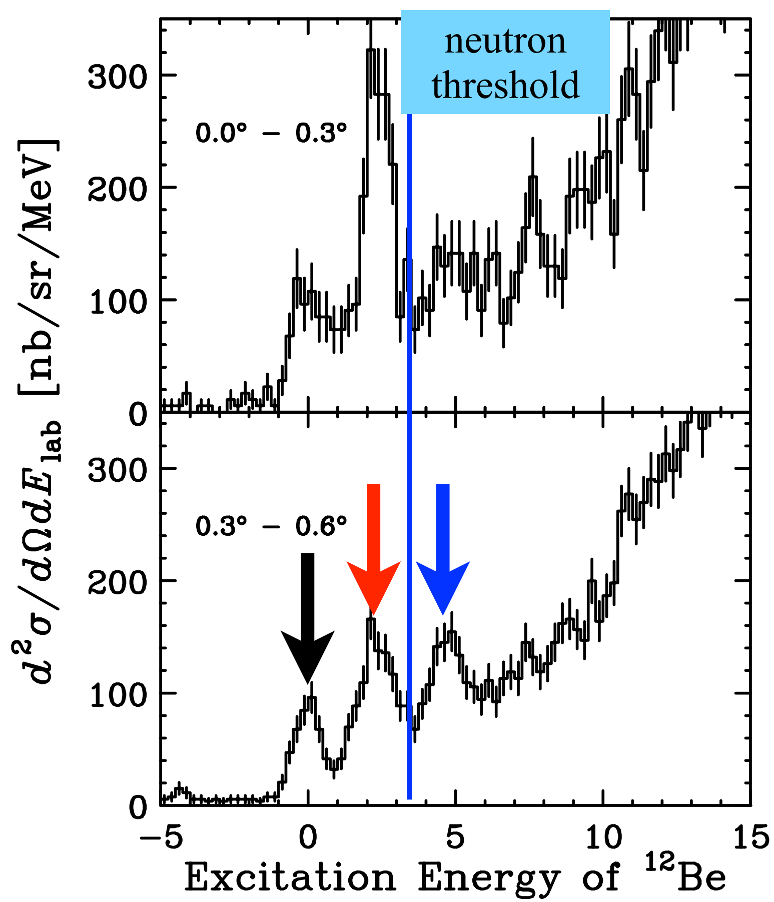
Excitation energy spectrum of ^{12}Be

- Ground and some excited states were clearly observed.

The first observation of the states via the HIDCX at an intermediate energy.



$^{12}C(^{18}O,^{18}Ne)^{12}Be$

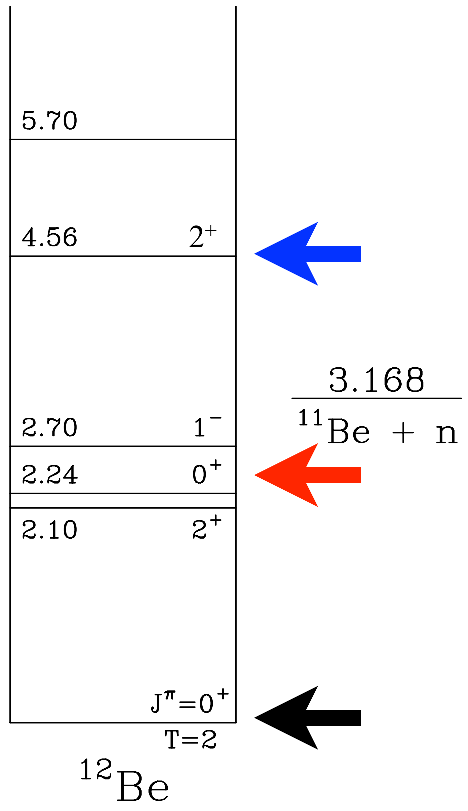


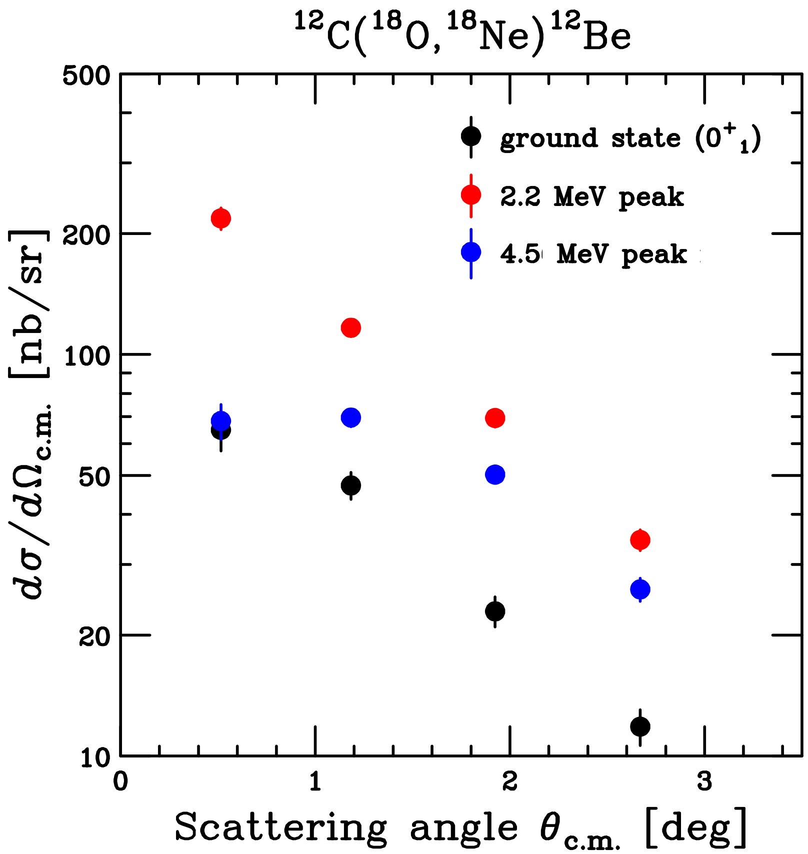
Capability of spin-parities assignment

Sensitive to multipolarities

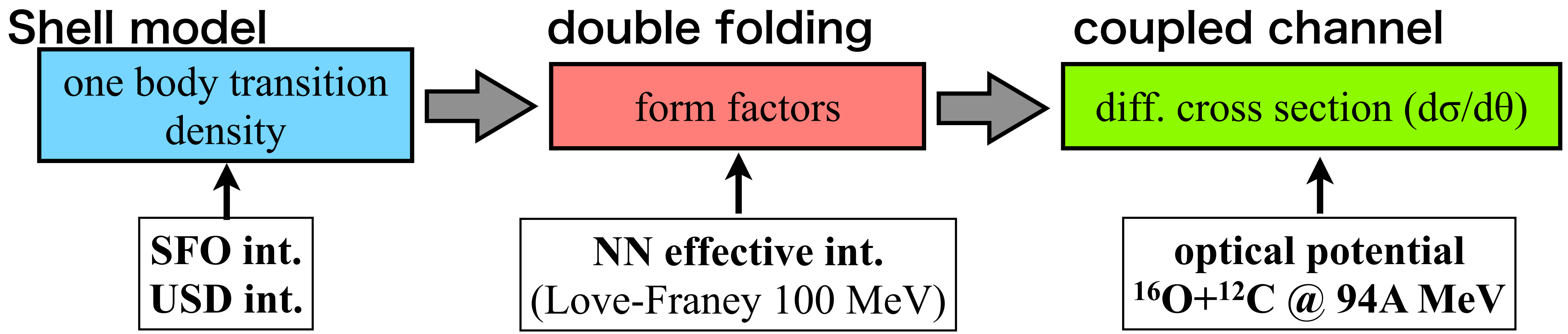
If the projectile transition is restricted between initial 0^+ state and final 0^+ state (ΔL=0, ΔS=0), only natural parity states are excited in the residual nuclei.

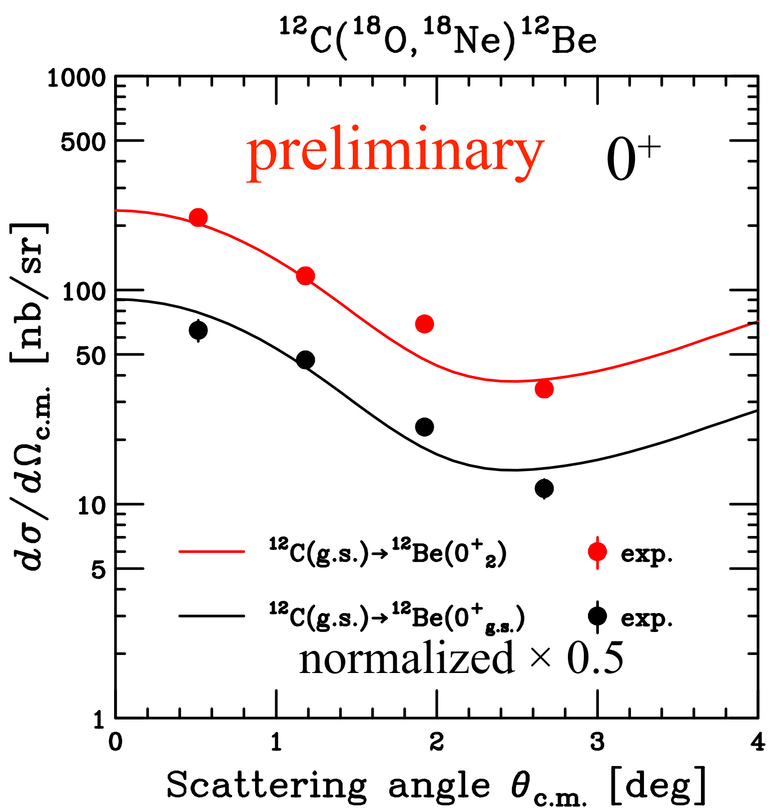
→ **spin-parity assignment**

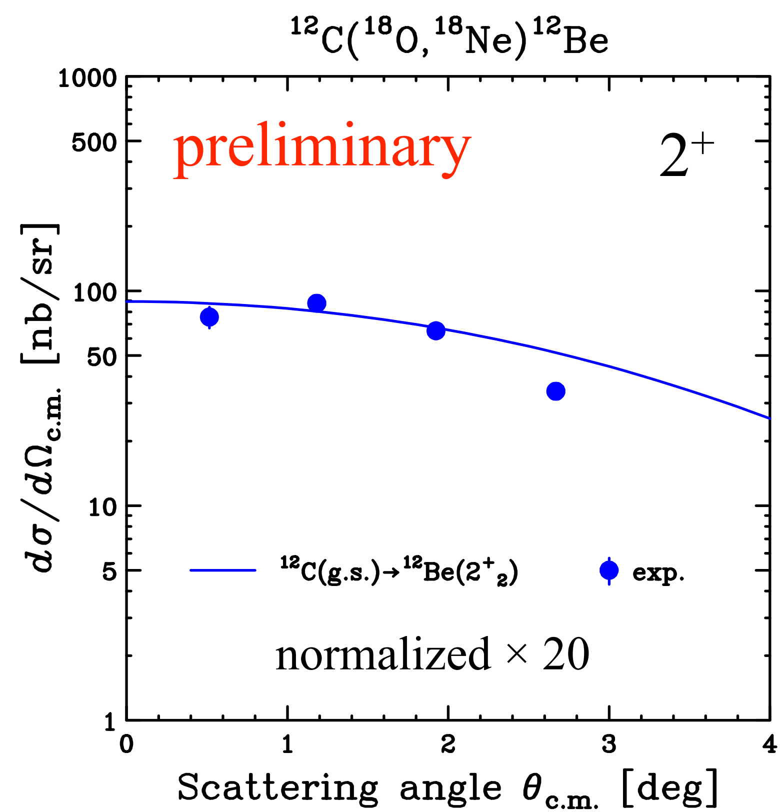




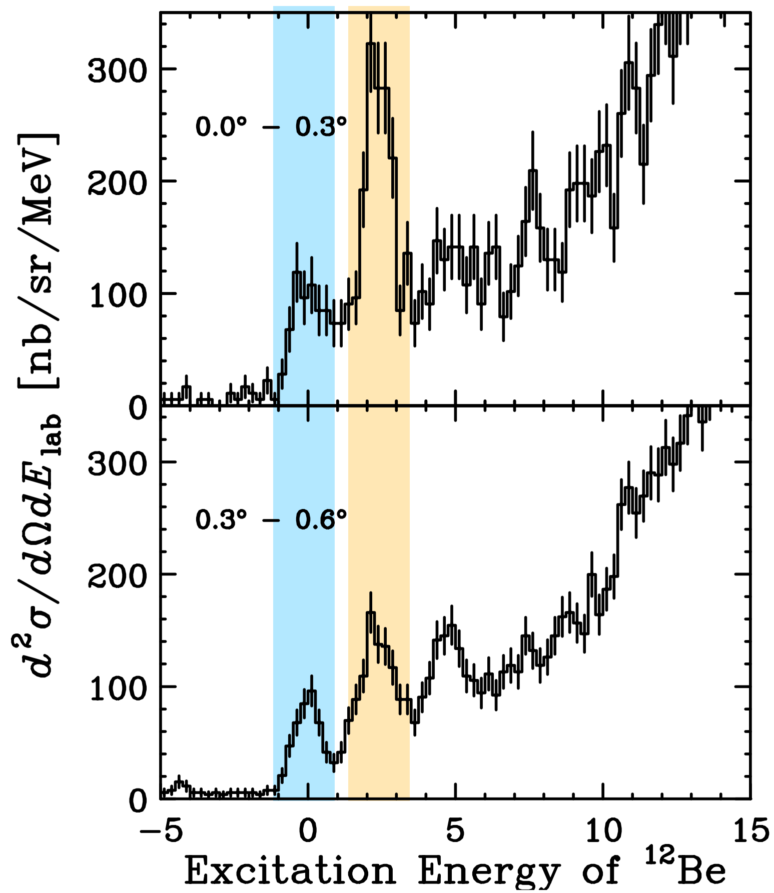
Reaction calculation of the HIDCX

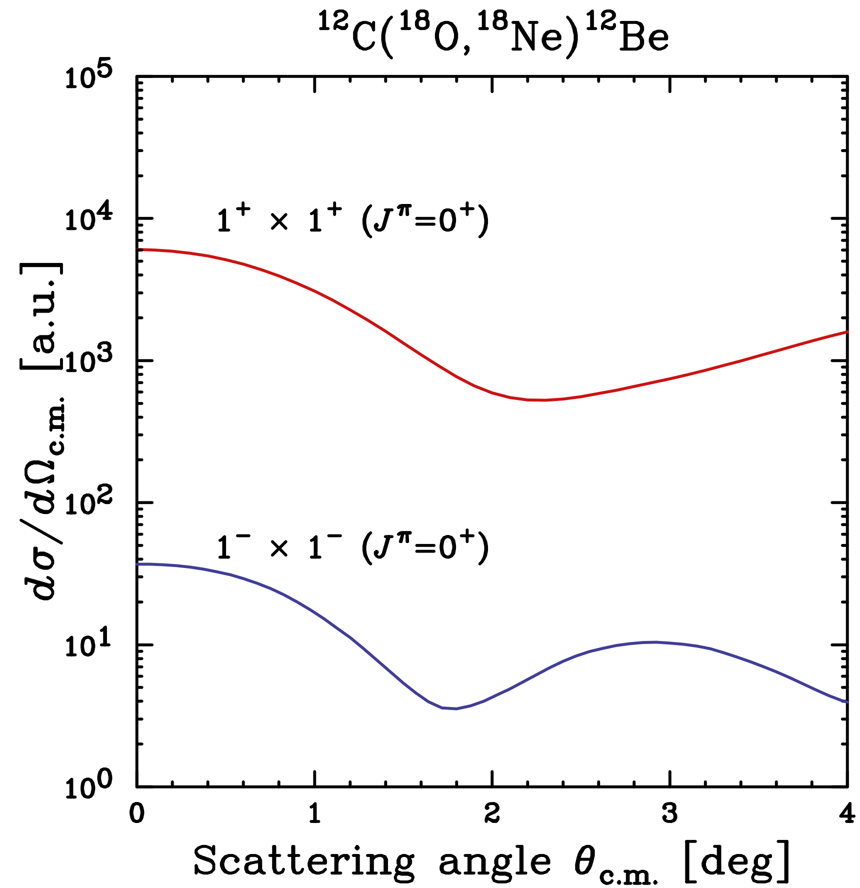






Dominance of double Gamow-Teller transition





Our experimental result

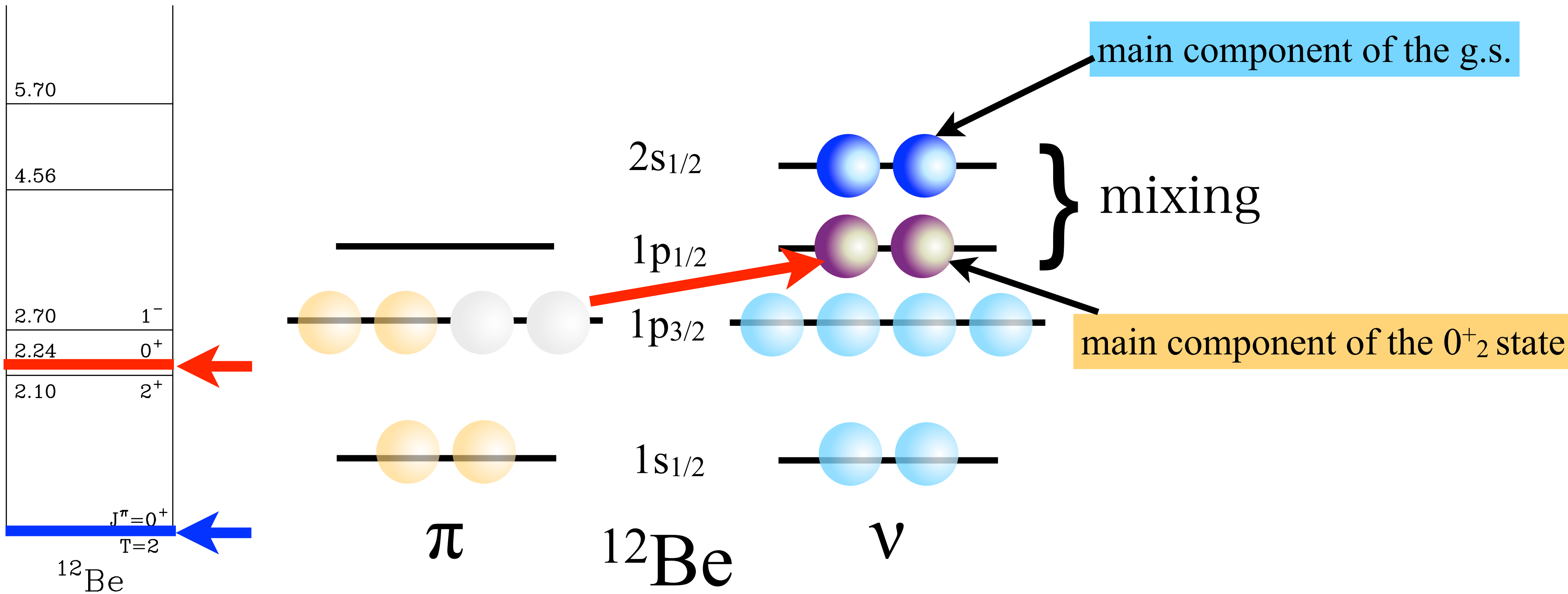
The cross section for the $0^+{}_2$ state is larger than $0^+{}_1$ (g.s.).

Double GT transitions dominate in this reaction.

→ Sensitive to the $0\hbar\omega$ ($1p_{1/2}$) configuration

Probing configuration mixing

Mixing degree between *p*- and *sd*-shell configurations in 0^+ states of ^{12}Be

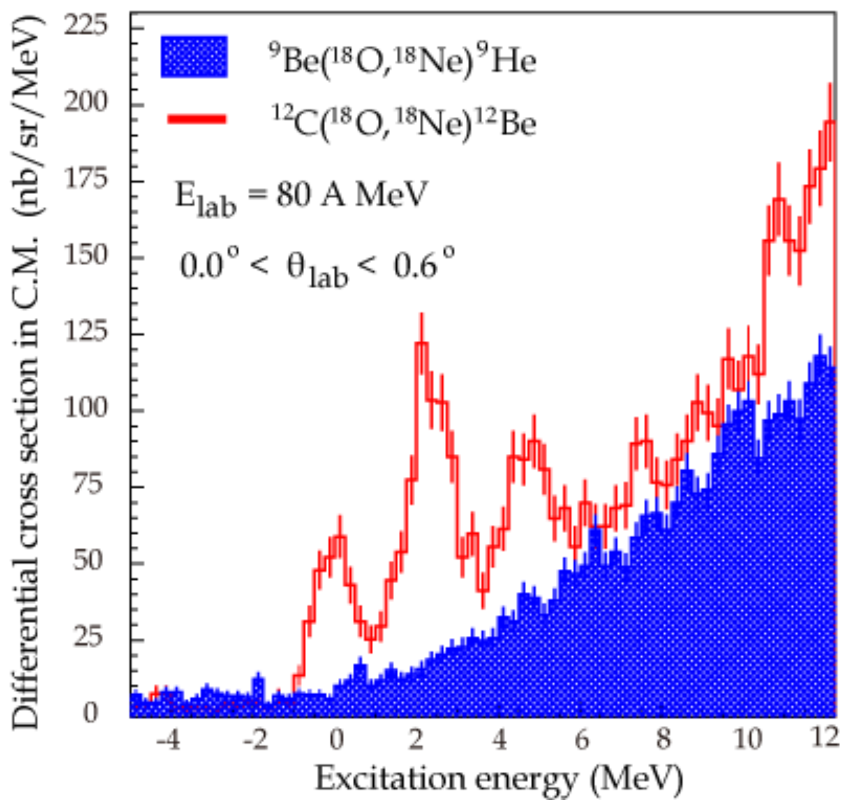


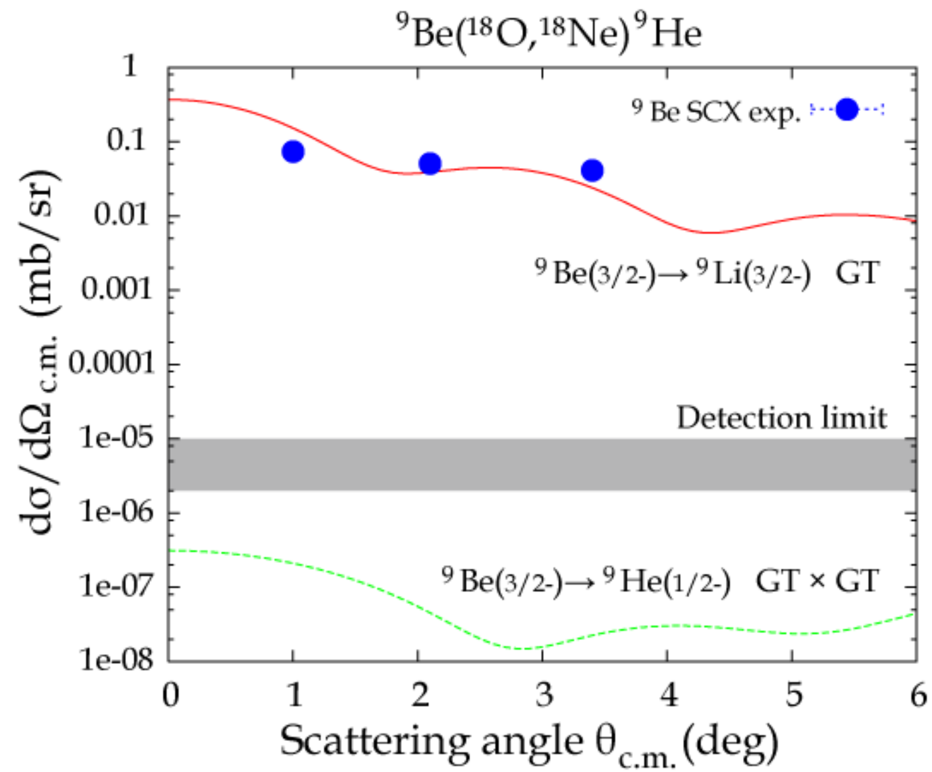
The larger cross section for the second 0^+ state is qualitatively consistent with earlier studies.

- **Future, MD analysis enables us the more quantitative discussion.**

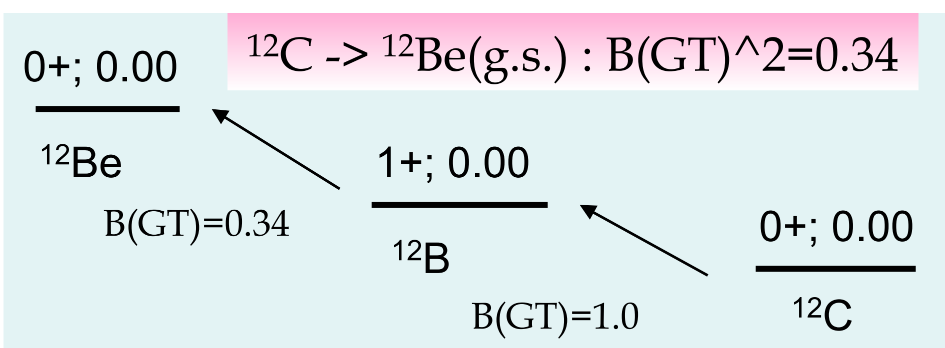
  →*p*-shell contribution to the 0^+ states in ^{12}Be can be deduced.

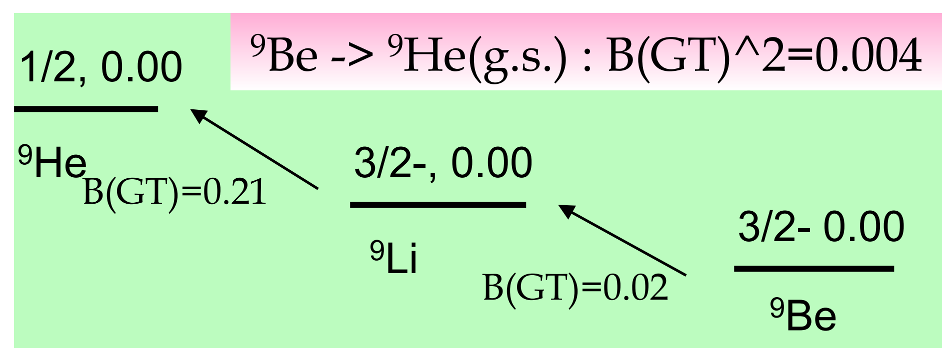
Result of ^{9}He





lower than detection limit





Small B(GT)×B(GT) value

Overview of our HIDCX studies

light Neutron-rich nuclei

β^+-type

1st trial

$^{12}C(^{18}O,^{18}Ne)^{12}Be$
$^{9}Be(^{18}O,^{18}Ne)^{9}He$
@ RCNP

$^{4}He(^{8}He,^{8}Be)4n$
@ RIBF

$^{13}C \rightarrow ^{13}Be$
$^{11}B \rightarrow ^{11}Li$

Heavy-ion double-charge exchange reaction
(HIDCX)

establishment as a spectroscopic tool

- experimental conditions
- reaction mechanism

β^--type

light Proton-rich nuclei

$^{12}C \rightarrow ^{12}O$

Double Gamow-Teller giant resonances

$^{48}Ca \rightarrow ^{48}Ti$

Summary

- We have developed β^+-type HIDCX reaction as another probe for light neutron-rich nuclei.
- First experiment, $^{12}C(^{18}O,^{18}Ne)^{12}Be$ reaction measurement, was succeeded.
  - **Ground and some excited states of ^{12}Be were observed.**
  - **The angular distributions have the sensitivity to multipolarities.**
- The development of the reaction calculation method for the HIDCX reaction is in progress.
- Any states in ^{9}He were not observed due to the small B(GT) value.

- The HIDCX reaction can be a powerful spectroscopic tool for unstable nuclei. **The present study is the first step**.

Collaborators

- CNS, University of Tokyo

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- Kyoto University

  T. Kawabata

- Kyushu University

  S. Sakaguchi

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Thank you for your attention.