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

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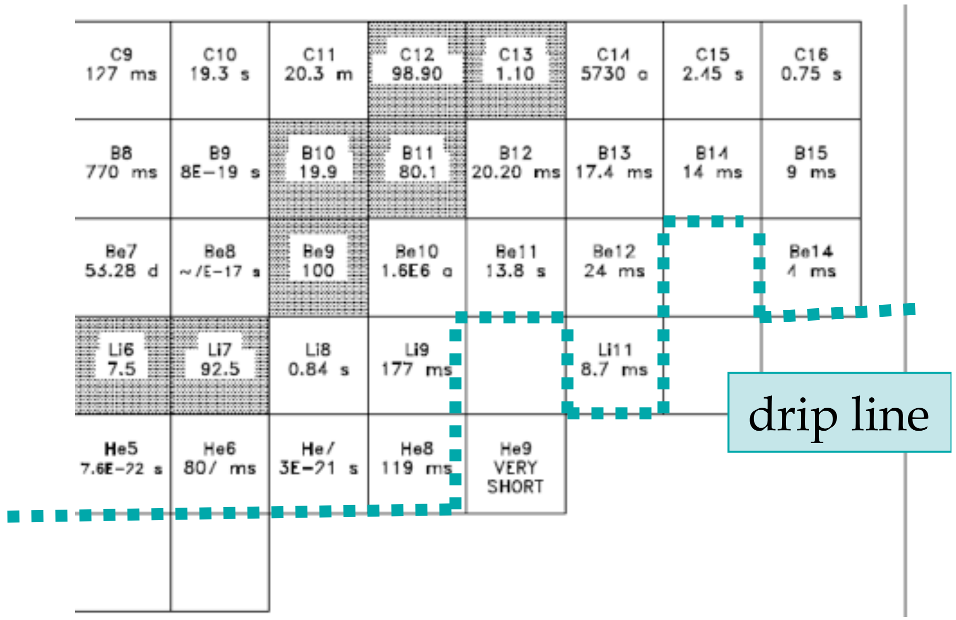
Conventional approach

Physics around the neutron drip line
- new magic number
- neutron halo
- neutron skin etc.

Conventional approach is

➡ [Unstable nucleus beam with projectile fragmentation reaction]



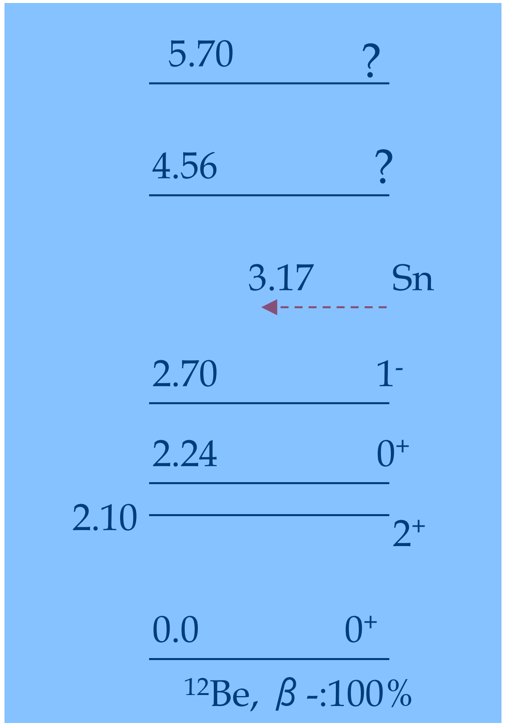
- γ-ray spectroscopy
- invariant-mass measurement
- inverse kinematical reaction etc.

We have to select appropriate measurement technique depending on a situation.

Neutron rich nuclei ^{12}Be and ^{9}He

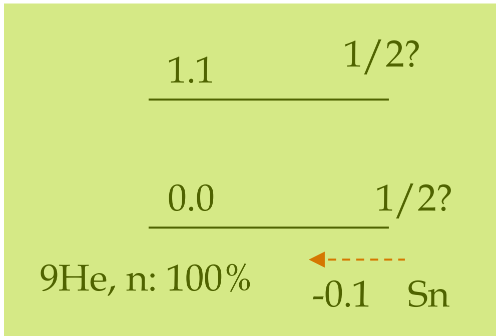
^{12}Be

- spin-parities at low-lying states are well known
- but those at high-lying states are unknown



^{9}He

-the largest A/Z ratio (4.5)
-unbound nucleus
- spin-parities are not fixed

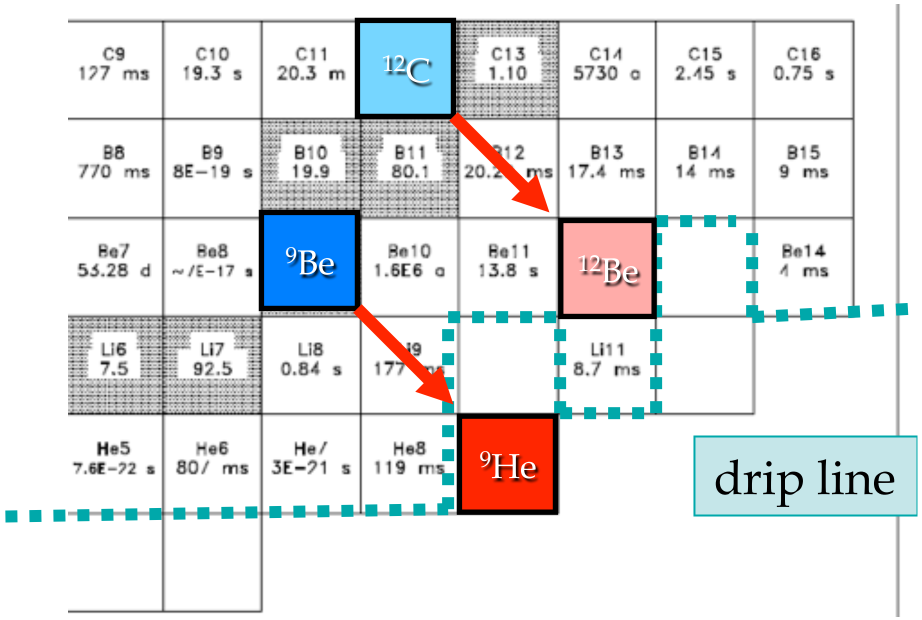


New approach to ^{9}He or ^{12}Be

How can we approach ^{9}He and ^{12}Be?

Double β + type transition

- from stable target
- beyond the drip line



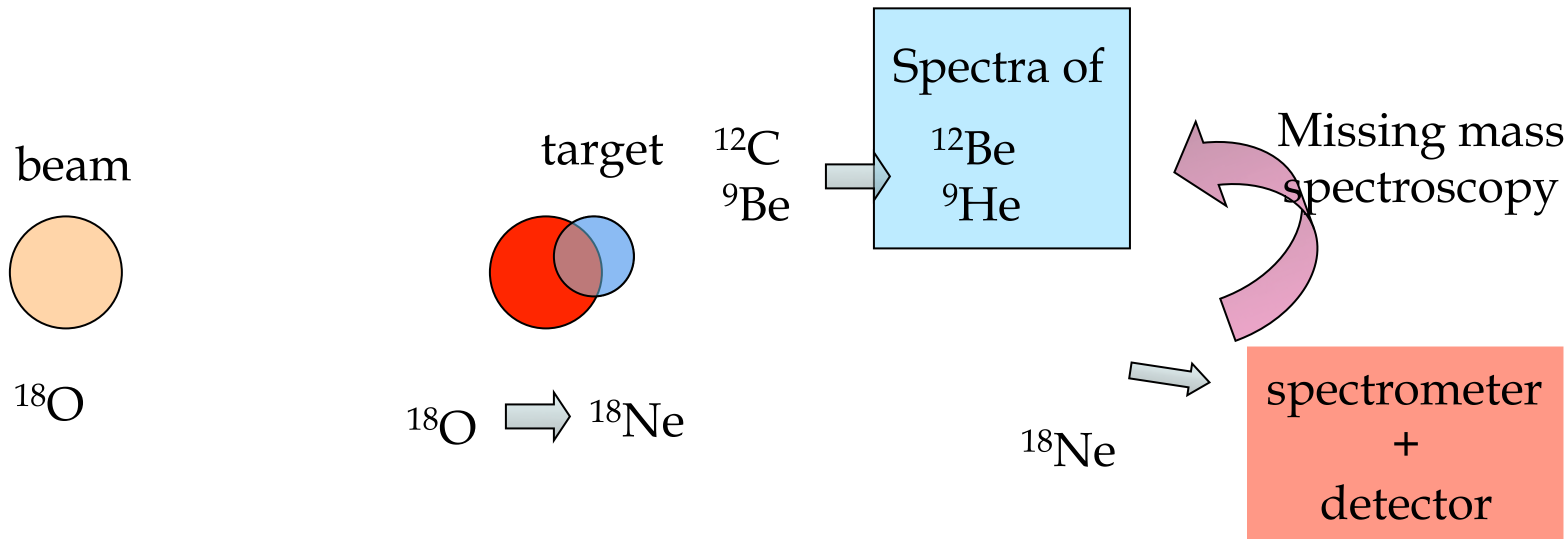
Double charge exchange reaction with heavy ion

⇨ HIDCX (heavy ion double charge exchange reaction)

What's HIDCX?

Heavy-ion double charge exchange reaction (HIDCX)

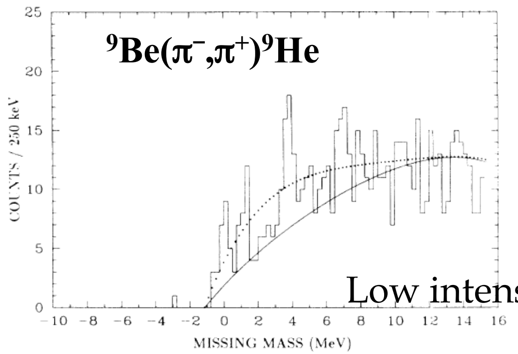
- A new tool to study light neutron rich nuclei
- Missing mass spectroscopy by using a magnetic spectrometer
  - One-shot measurement <u>below and beyond the particle threshold</u>
  - No limitation in terms of the drip line
- We are proposing the (^{18}O,^{18}Ne) reaction at medium energy
  - Normal kinematical reaction



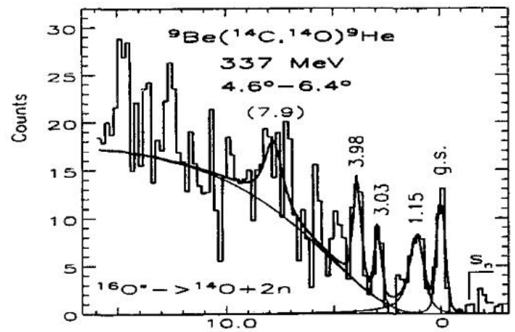
Why HIDCX at medium energy?

Previous DCX works :

- Pion DCX reaction, (π-, π+) by K.K. Seth
- Heavy ion DCX reaction at low energy (~20 MeV/u) by H.G. Bohlen
- No information about angular distribution



Low intensity



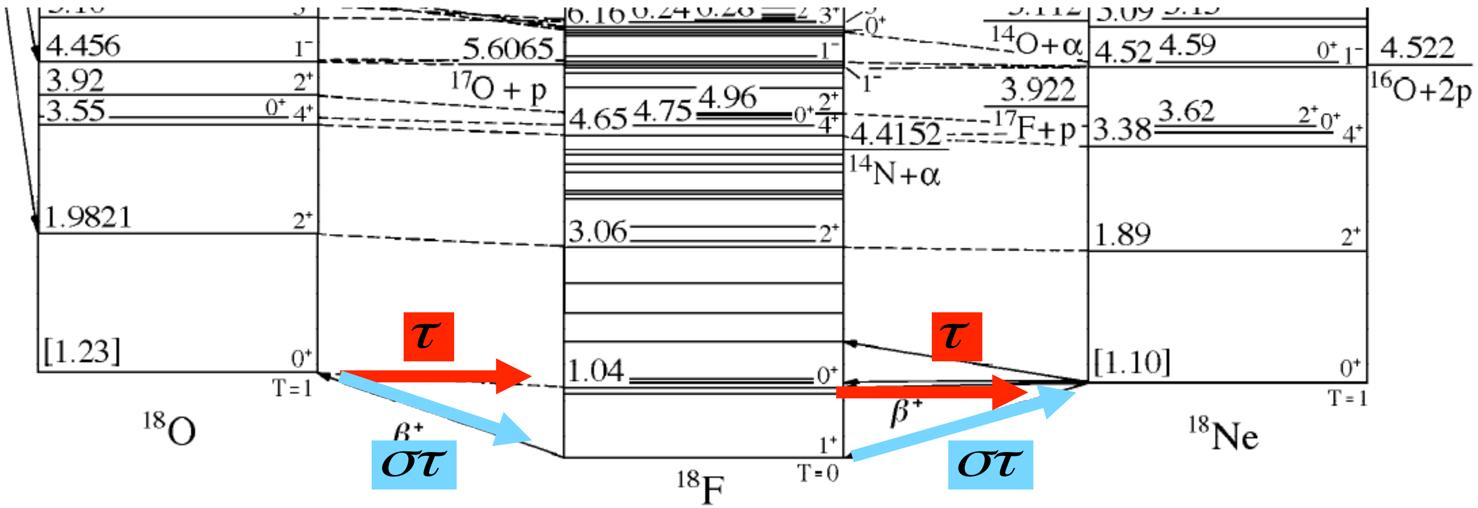
Multi-step reaction

Proposing HIDCX at medium energy :

- Primary beam experiment (^{18}O is stable)
  - High intensity
- At medium energy (80 MeV/u)
  - Simpler reaction mechanism is expected
- Additional information of angular distribution
  - ΔL assignment

Why (^{18}O,^{18}Ne) reaction as HIDCX?

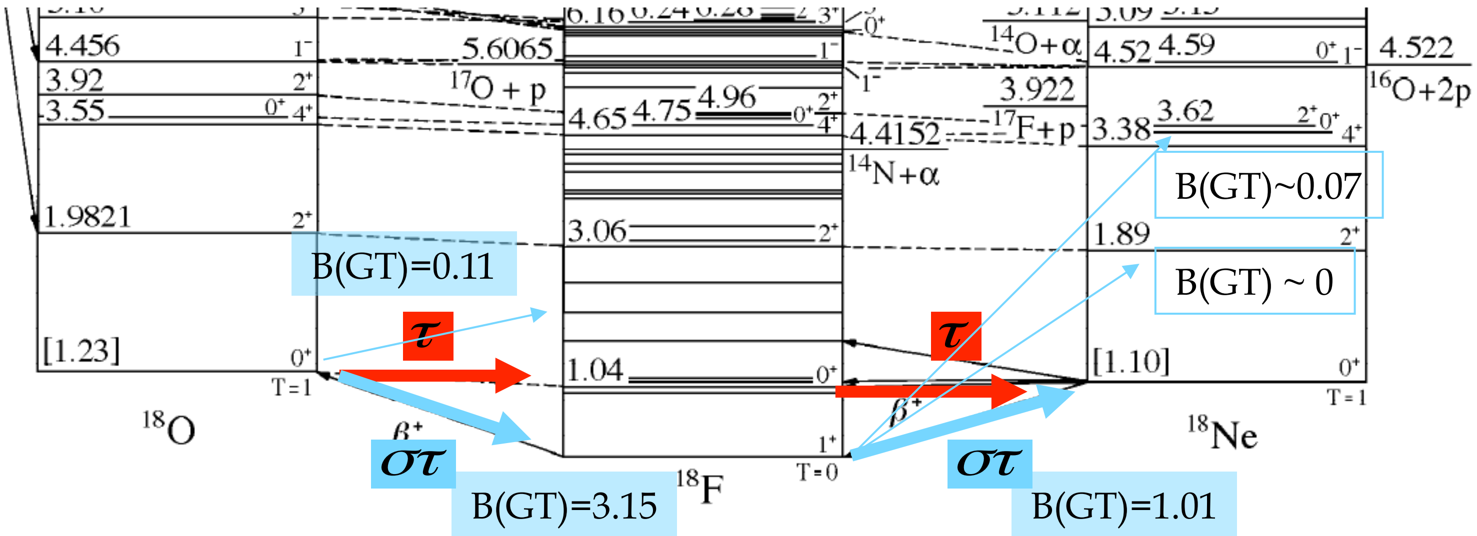
Transition in super multiplet members



1. Large overlapping of wavefunction in r-space
   → large reaction rate

Why (^{18}O,^{18}Ne) reaction as HIDCX?

Transition in super multiplet members

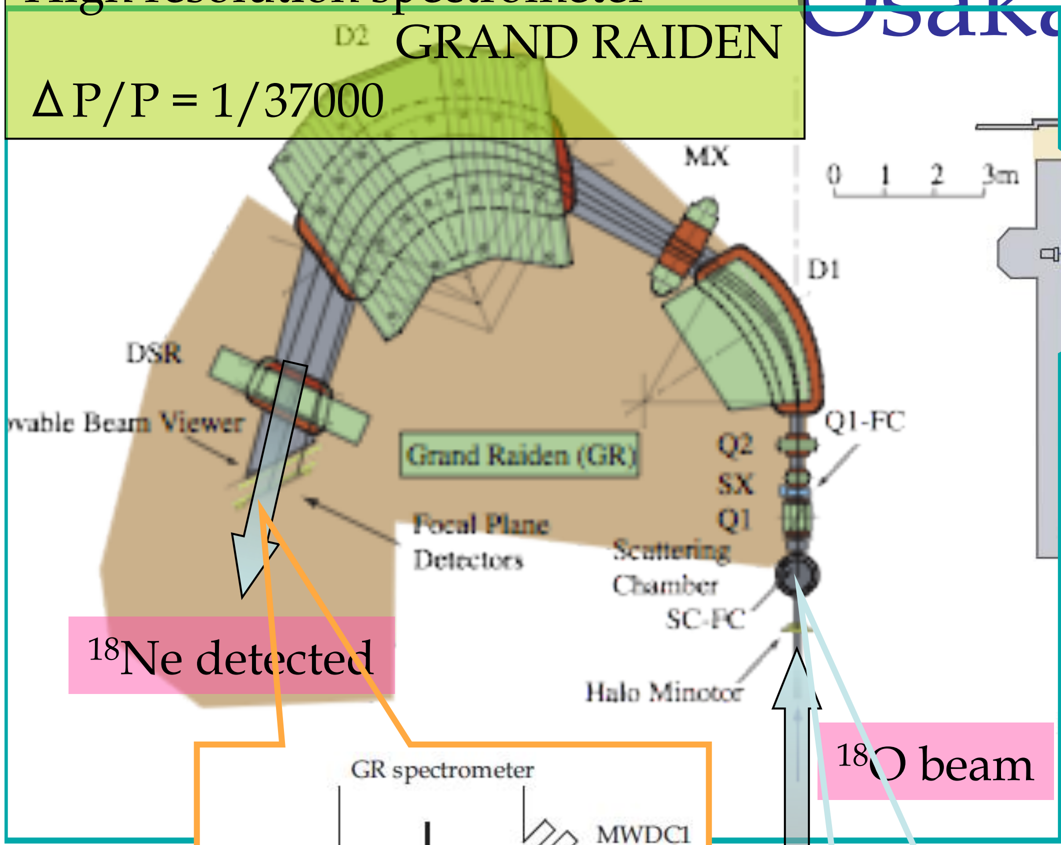


1. Large overlapping of wavefunction in r-space
   → large reaction rate

2. Negligible contribution of excited states in ^{18}Ne

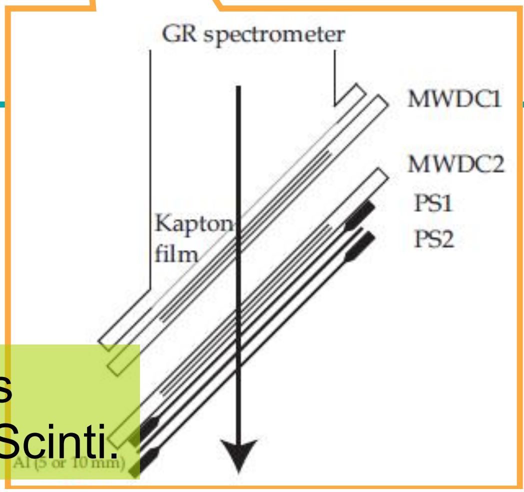
Research Center for Nuclear Physics, Osakas

High resolution spectrometer
GRAND RAIDEN
$\Delta P/P = 1/37000$



^{18}Ne detected

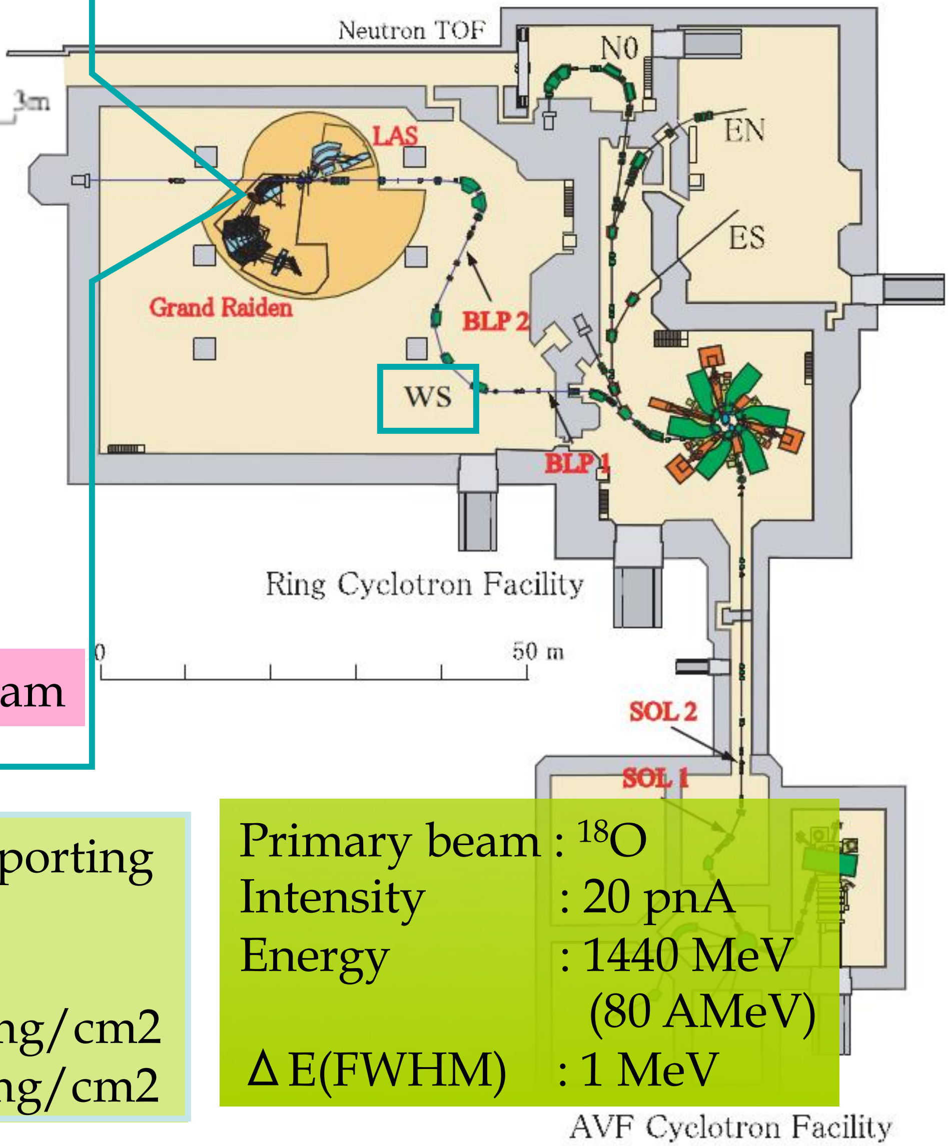
^{18}O beam



MWDCs
Plastic Scinti.

Self-supporting target

^{9}Be 5.2 mg/cm2
^{12}C 2.2 mg/cm2



Primary beam : ^{18}O
Intensity : 20 pnA
Energy : 1440 MeV
(80 AMeV)
ΔE(FWHM) : 1 MeV

Successful particle identification

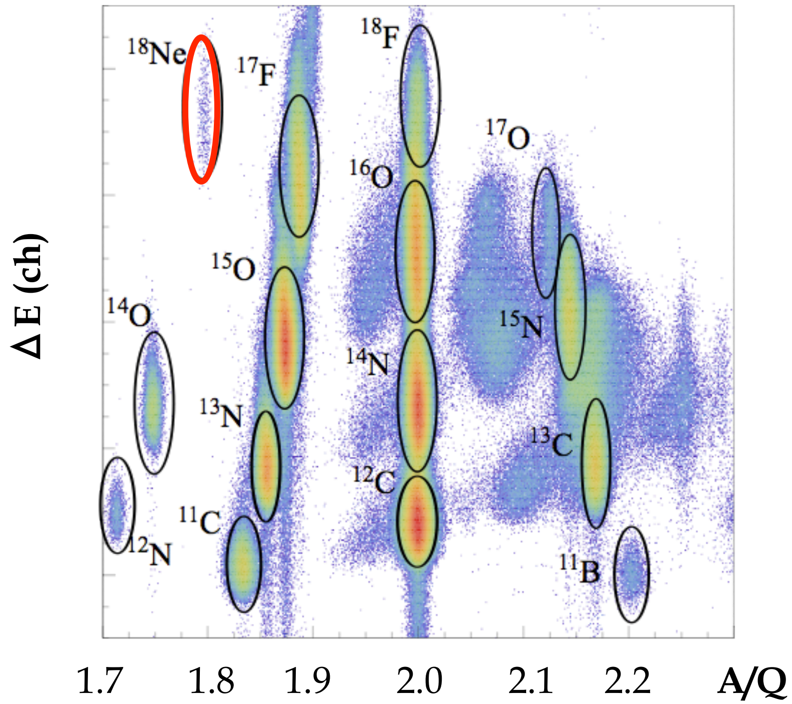
PI for ^{18}Ne was realized
mainly by A/Q information.

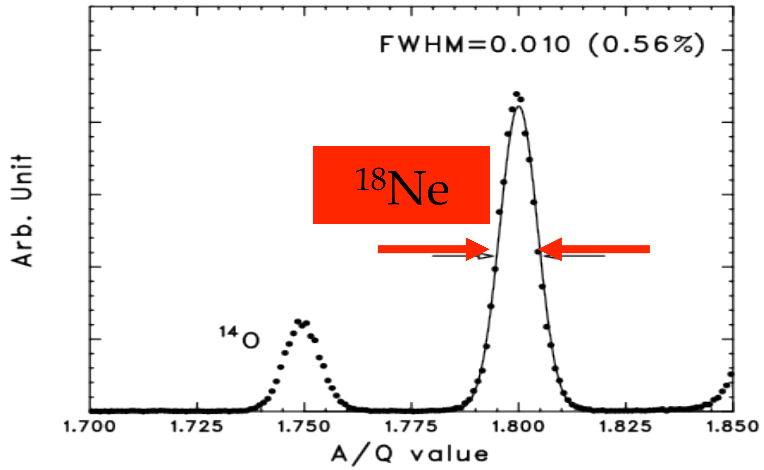
$$B\rho = \frac{p}{Q} = \frac{A m_N \beta\gamma}{Q} \Rightarrow \frac{A}{Q} = \frac{B\rho}{\beta\gamma m_N}$$

A/Q value of 9/5 is unique for ^{18}Ne.

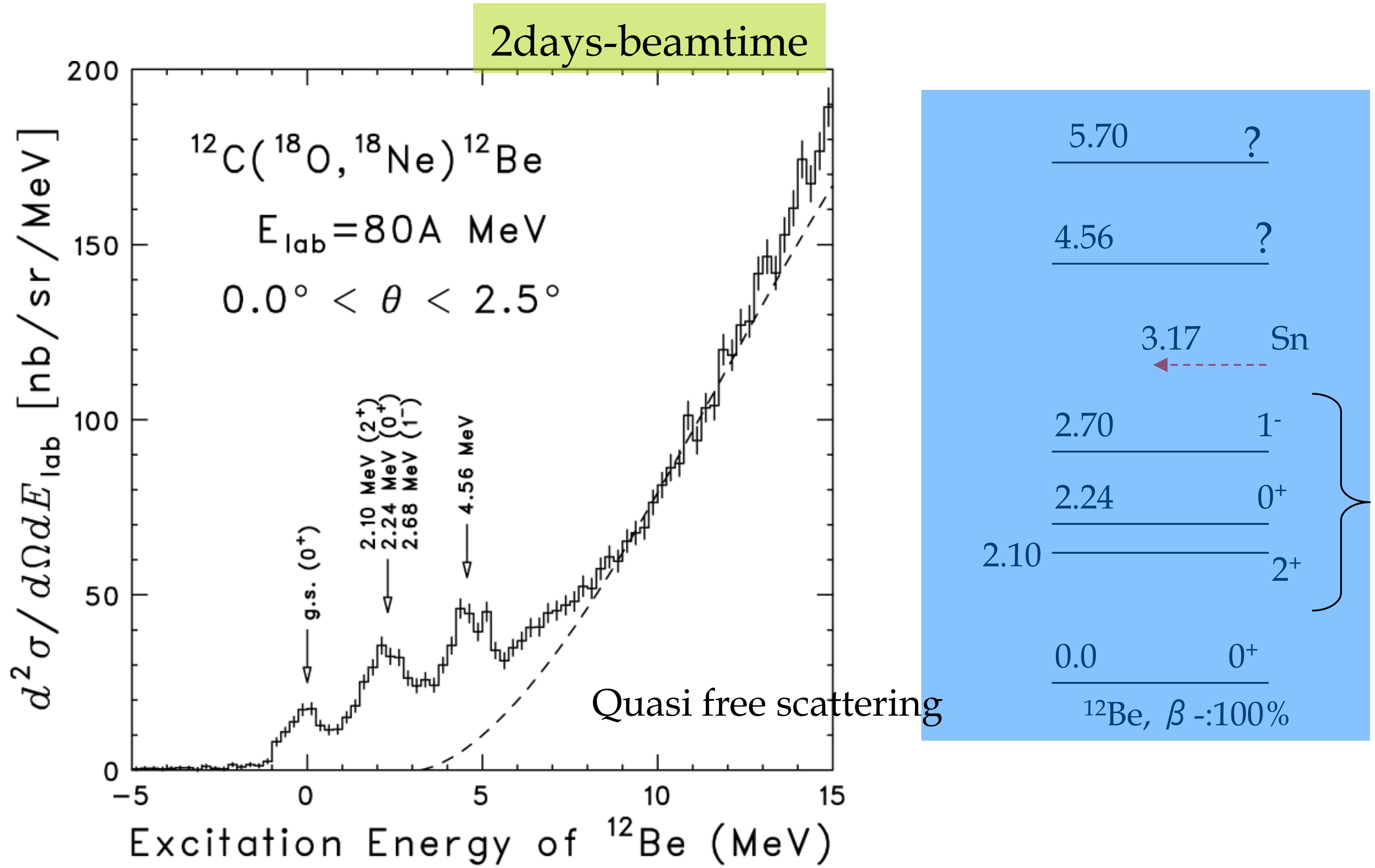
(^{9}B nucleus is unbound.)

Good particle identification
for ^{18}Ne was realized.



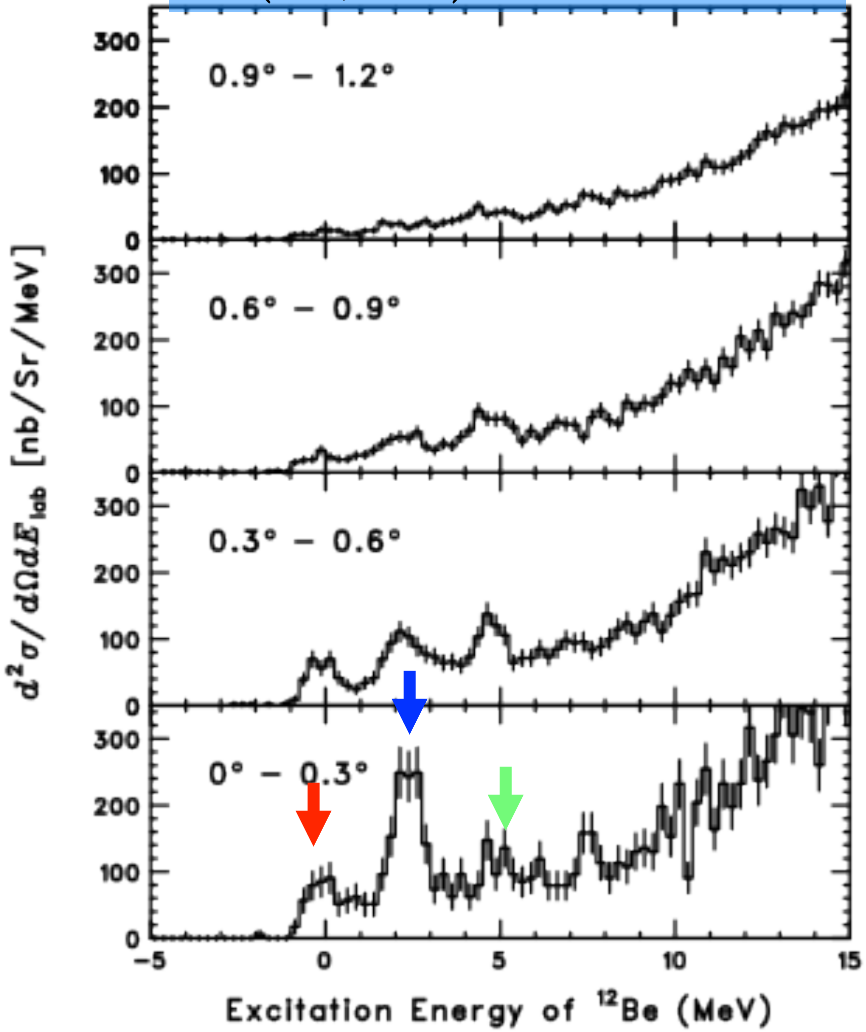


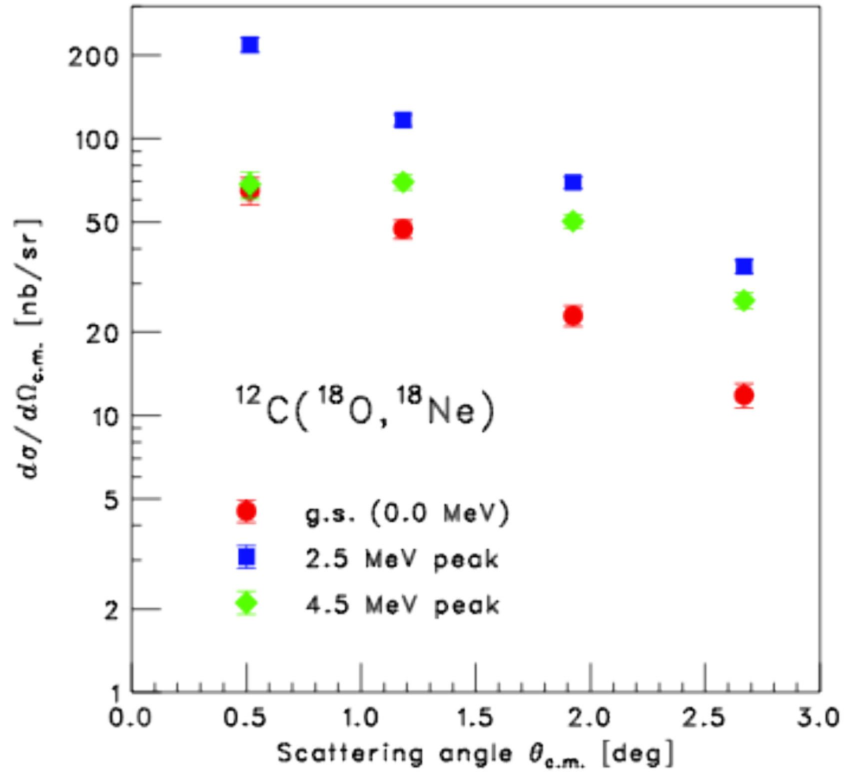
Clear peaks in energy spectra of ^{12}Be



Can we learn more ?

$^{12}C(^{18}O,^{18}Ne)^{12}Be$ at 80 AMeV

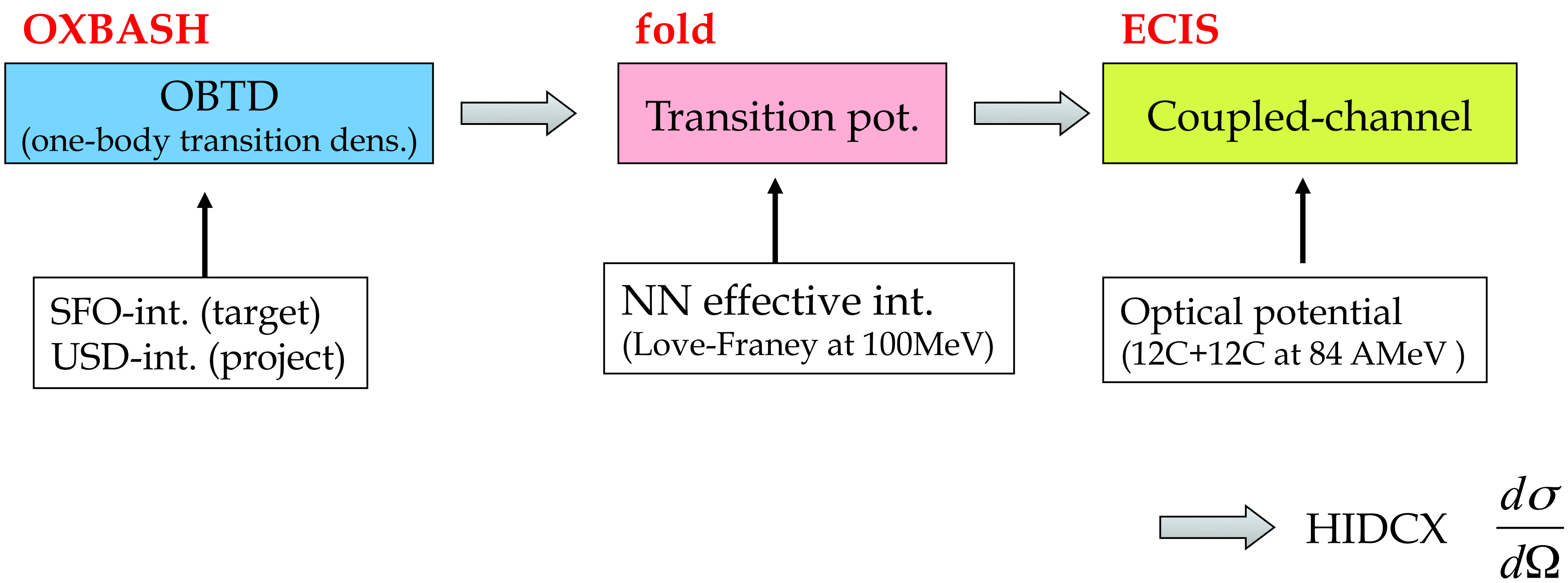




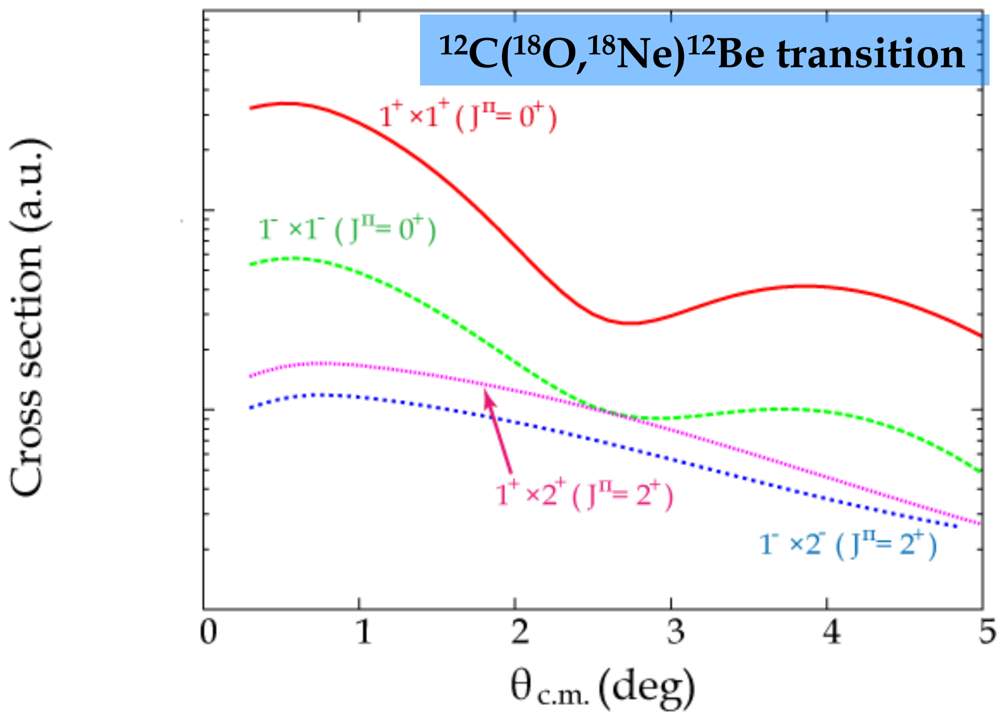
Suggesting
 the same spin-parity for g.s. and 2.5MeV
 different on for 4.5 MeV from the others

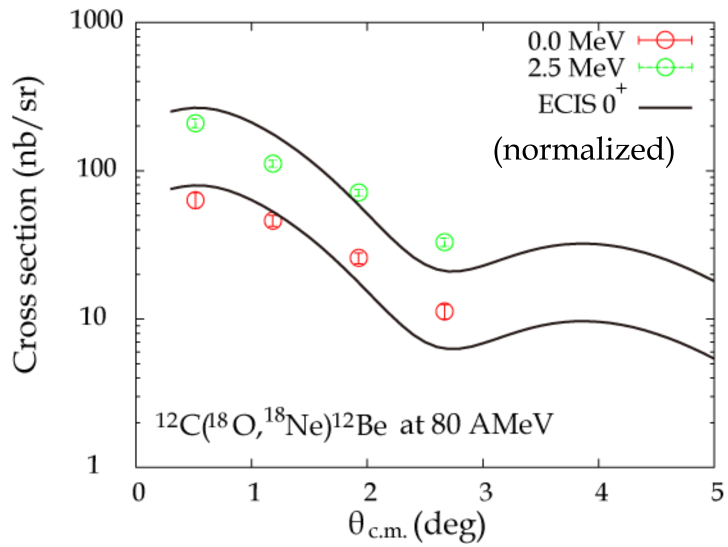
DCX calculation

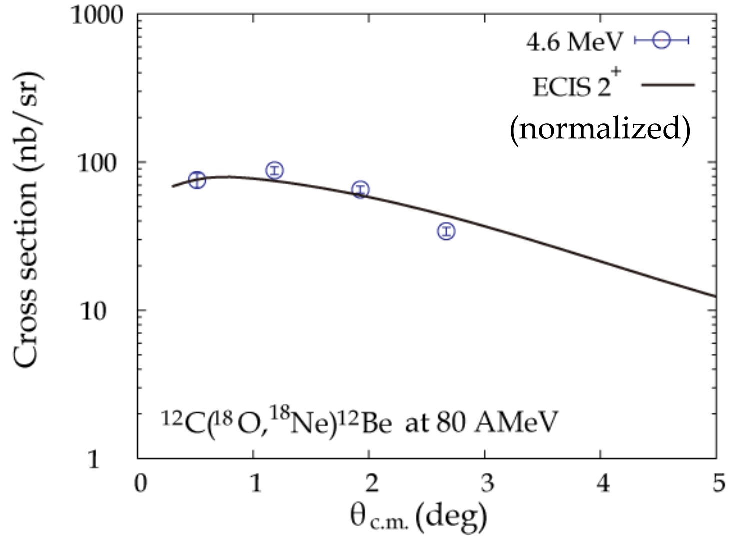
- Coupled-channel calculation (ECIS 97)
  - Assuming two-phonon modes
  - Transition potential by double-folding



J^{π}-assignment



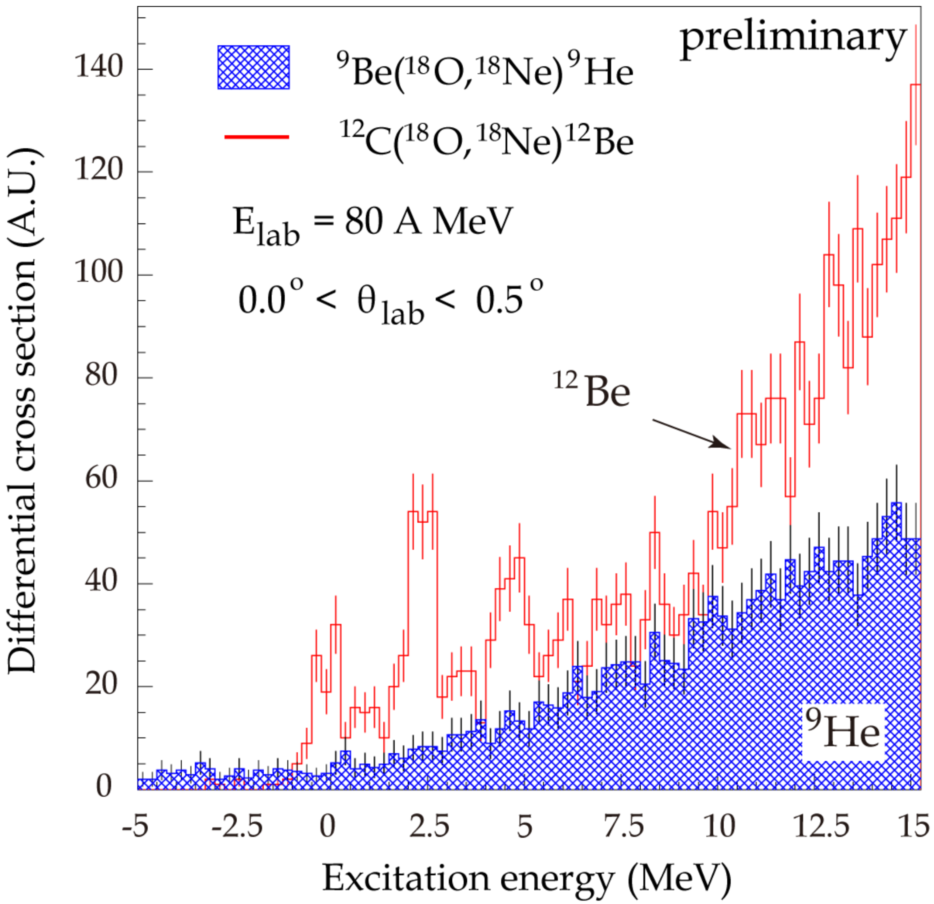




1. Multi-polarity can be assigned.

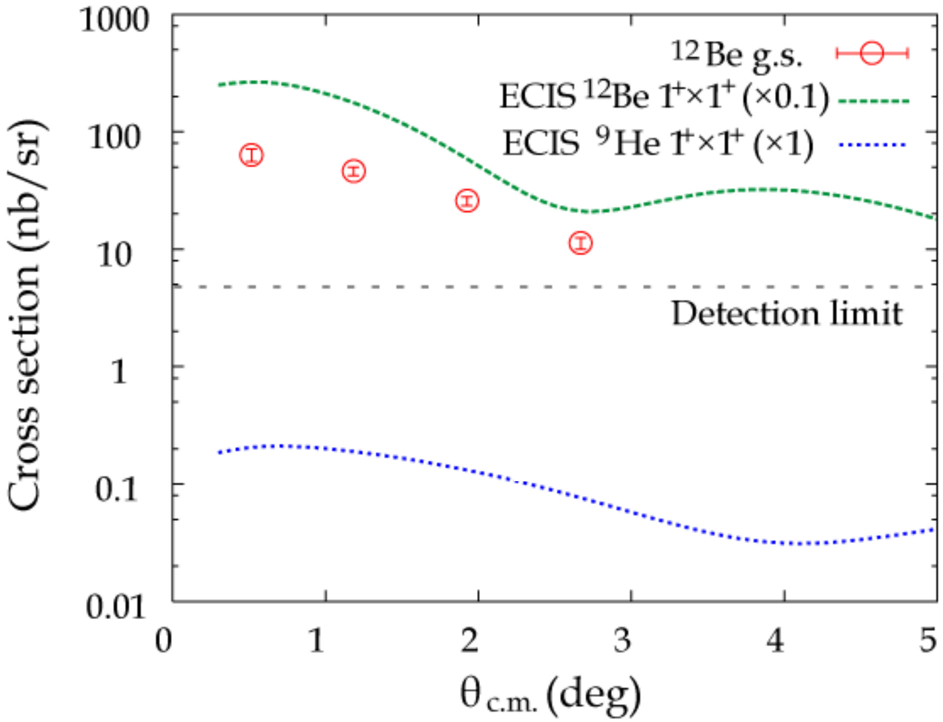
2. It does not depend on an intermediate state.

Energy spectrum of ^{9}He

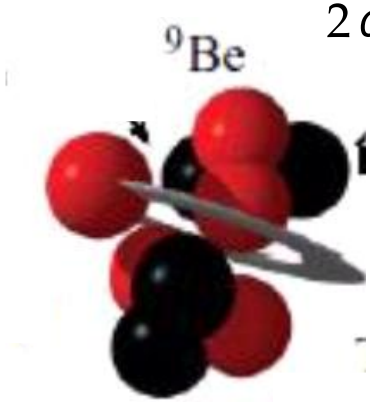


Why no peaks ?

Why no peaks in ^{9}He ?



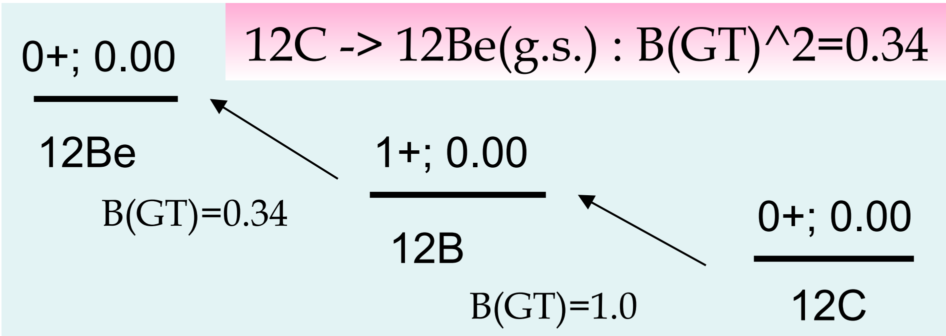
$2\alpha + n$ picture

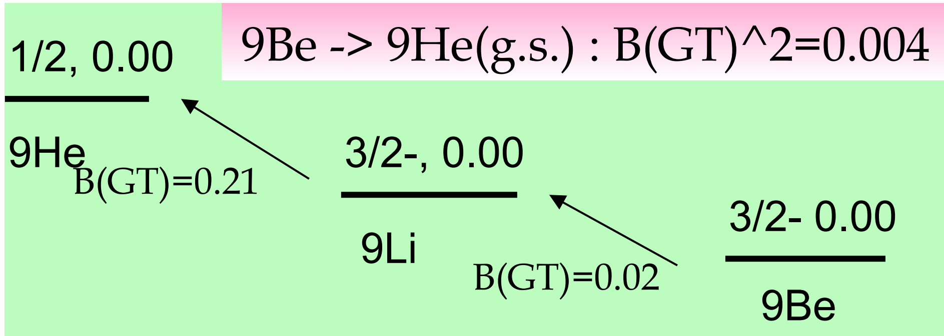


For expample, C.Scholl et al. PRC (2011)

Even simple calculation can reproduce a magnitude of DCX cross section.

SFO interaction





Summary

- Proposing HIDCX reaction at medium energy was tested.
- Angular distribution of c.s allows us to determine multi polarity.
  - 4.56 MeV in ^{12}Be has been assigned as 2^+ state.
- No peaks were observed in ^{9}He owing to small B(GT) value, which is consistent with the simple calculation.
- We established a first step for the HIDCX to be a new tool for light neutron rich nuclei.

Thank you for your attention

Future plan for HIDCX

- Improvement of Experiment
  - Beam intensity (10 times larger)
  - Energy resolution (1MeV →0.3 MeV)

- Target nuclei
  - ^{10}Li (unbound but expected as ~20 nb/sr)