北京航空航天大學
BEIHANG UNIVERSITY

Probing effect of tensor interactions in nuclei via (p, d) reaction

Guo Chenlei

(On behalf of RCNP-E396)

Research Center of Nuclear Science and Technology (**RCNST**)

Beihang University

HST15 INTERNATIONAL SYMPOSIUM ON HIGH-RESOLUTION SPECTROSCOPY & TENSOR INTERACTIONS

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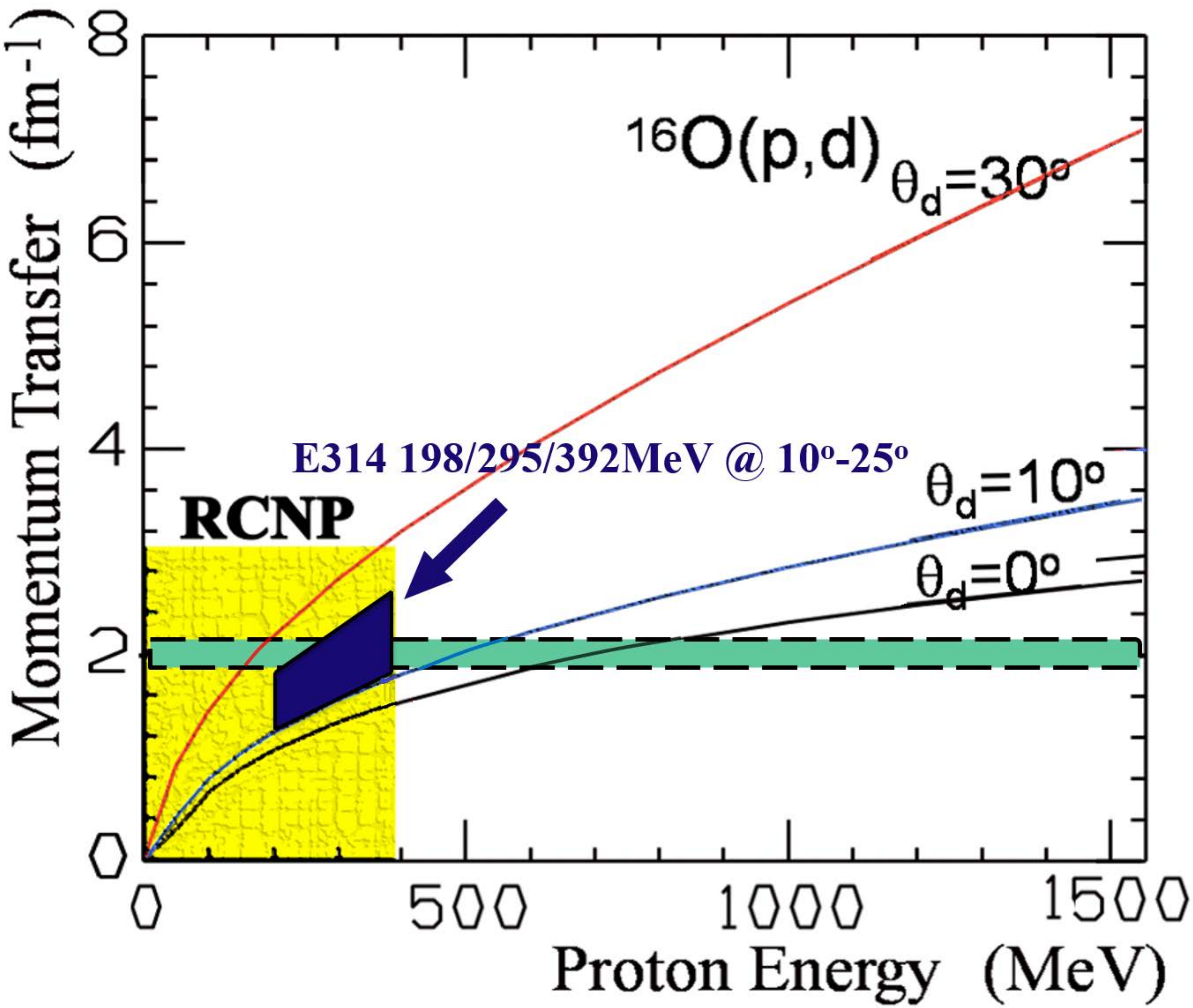
- Physics Motivation (Already talked a lot in this symposium…)
- Experiments in RCNP, Osaka
- Preliminary results & Discussion
- Summary & Acknowledgments

Nucleon pick-up reaction($^{12}C(p,d)$ & $^{16}O(p,d)$) @ RCNP, Osaka



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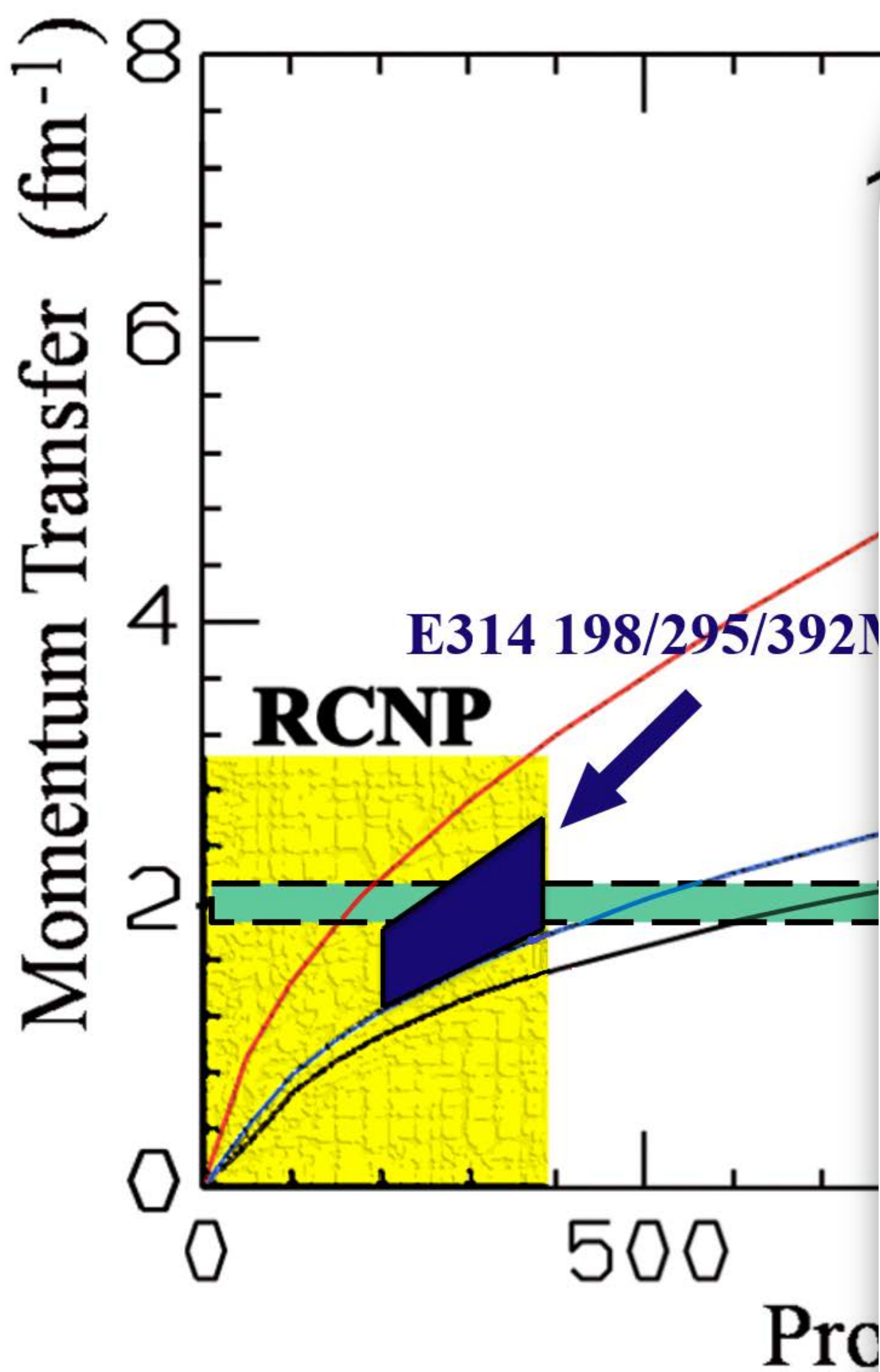

Physics Letters B 725 (2013) 277–281

Contents lists available at SciVerse ScienceDirect

Physics Letters B

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Probing effect of tensor interactions in ^{16}O via (p, d) reaction

H.J. Ong [a,*], I. Tanihata [a,b], A. Tamii [a], T. Myo [a,c], K. Ogata [a], M. Fukuda [d], K. Hirota [a], K. Ikeda [e], D. Ishikawa [a], T. Kawabata [f], H. Matsubara [a,1], K. Matsuta [d], M. Mihara [d], T. Naito [a], D. Nishimura [d,2], Y. Ogawa [a], H. Okamura [a], A. Ozawa [g], D.Y. Pang [b], H. Sakaguchi [a], K. Sekiguchi [e], T. Suzuki [a], M. Taniguchi [h], M. Takashina [a], H. Toki [a], Y. Yasuda [a], M. Yosoi [a], J. Zenihiro [a,3]

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ABSTRACT

We have measured the ^{16}O(p, d) reaction using 198-, 295- and 392-MeV proton beams to search for a direct evidence on an effect of the tensor interactions in light nucleus. Differential cross sections of the one-neutron transfer reaction populating the ground states and several low-lying excited states in ^{15}O were measured. Comparing the ratios of the cross sections for each excited state to the one for the ground state over a wide range of momentum transfer, we found a marked enhancement of the ratio for the positive-parity state(s). The observation is consistent with large components of high-momentum neutrons in the initial ground-state configurations due to the tensor interactions.

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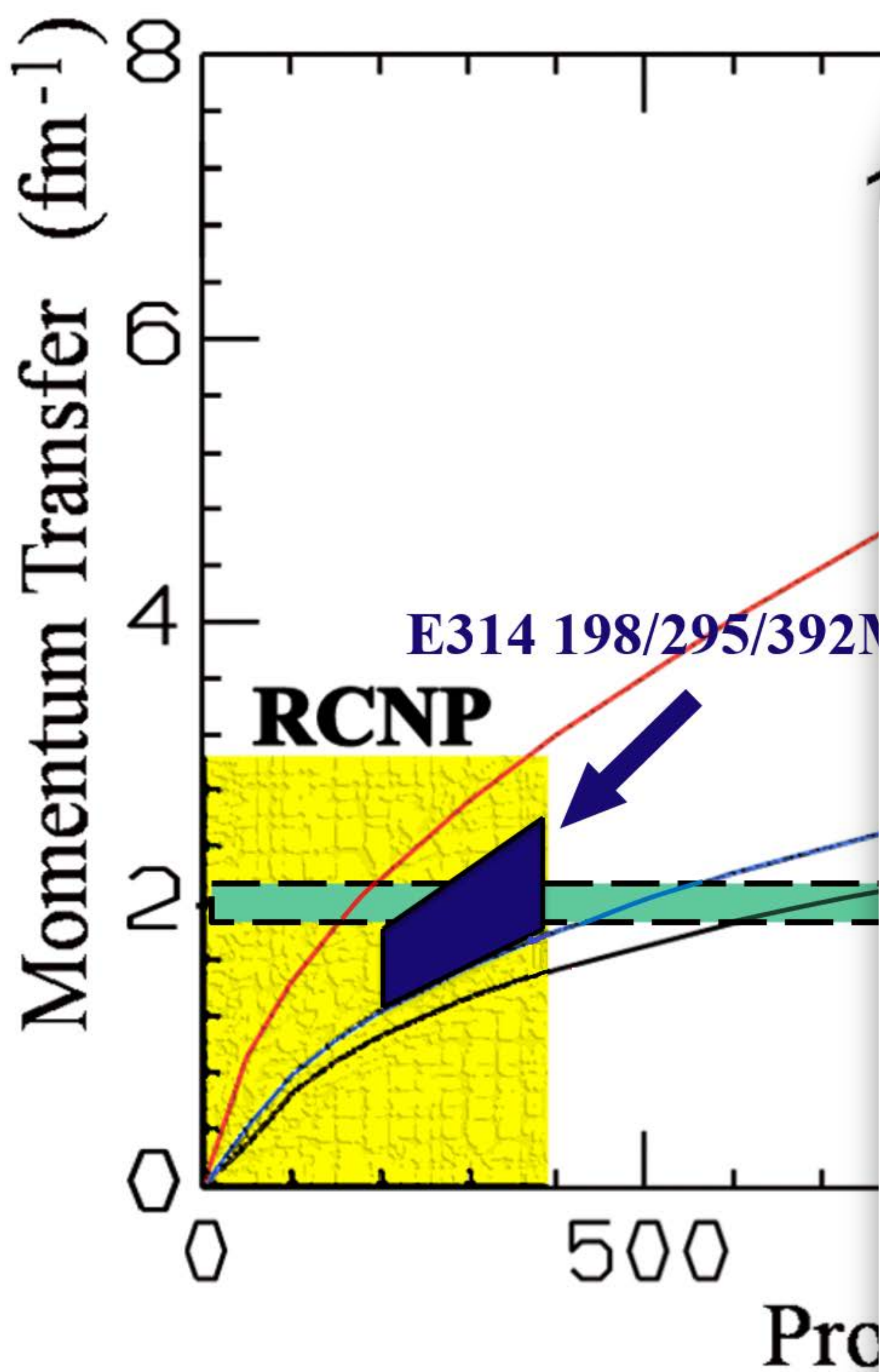

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a Res
b Sch
c Ger
d Dep
e RIK
f Dep
g Institute of Physics, Tsukuba University, Tsukuba, Ibaraki 305-8571, Japan
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Further question has been asked: reaction mechanism effect at finite angle

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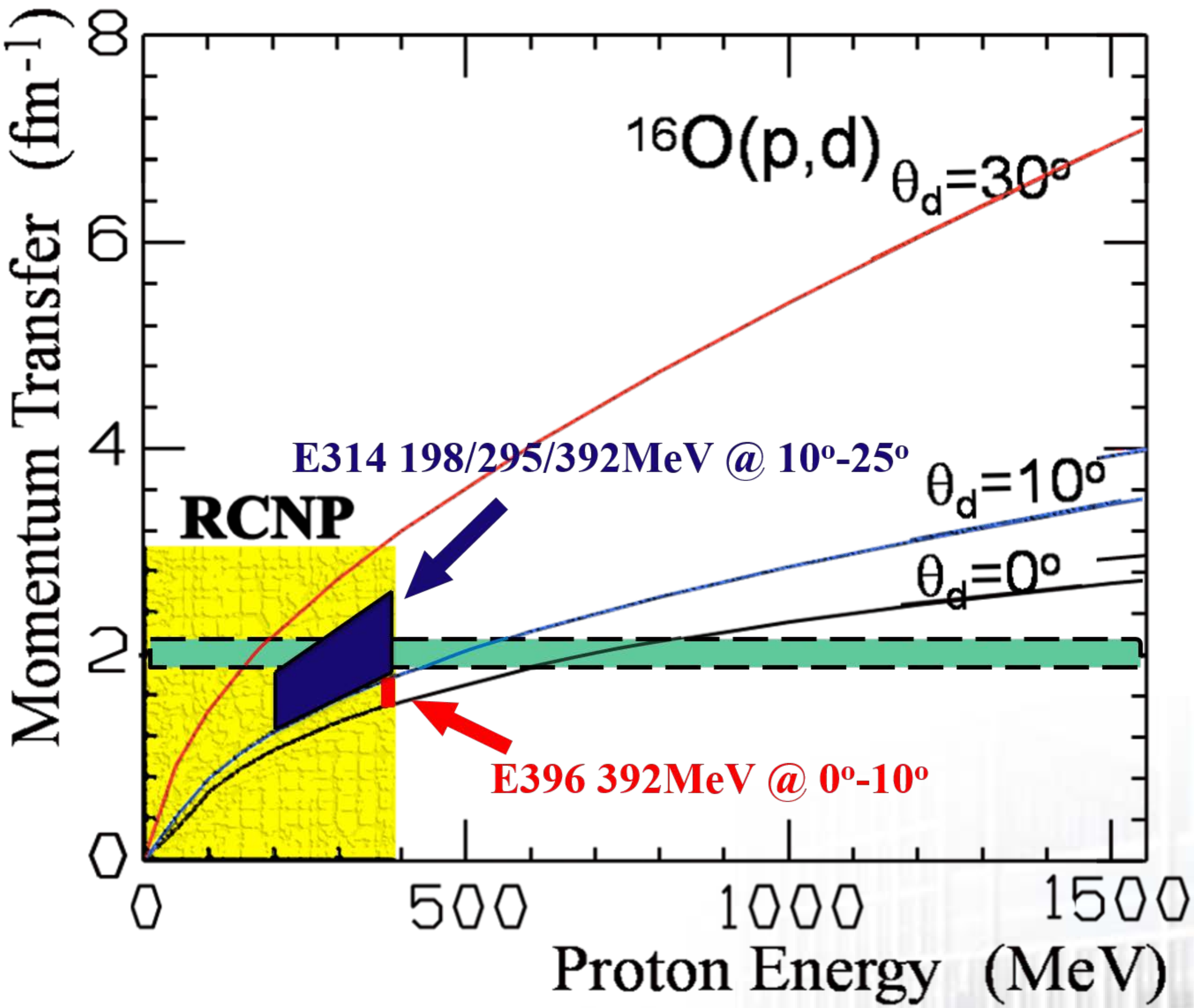
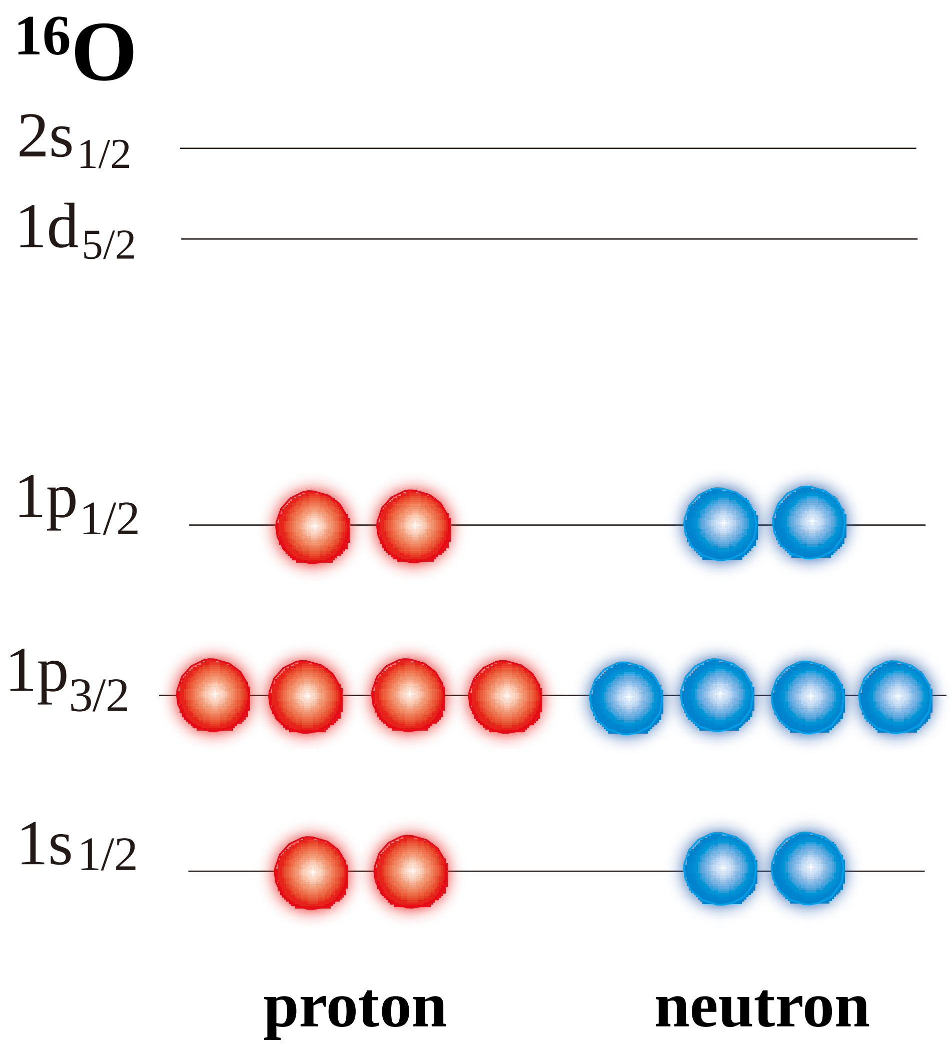
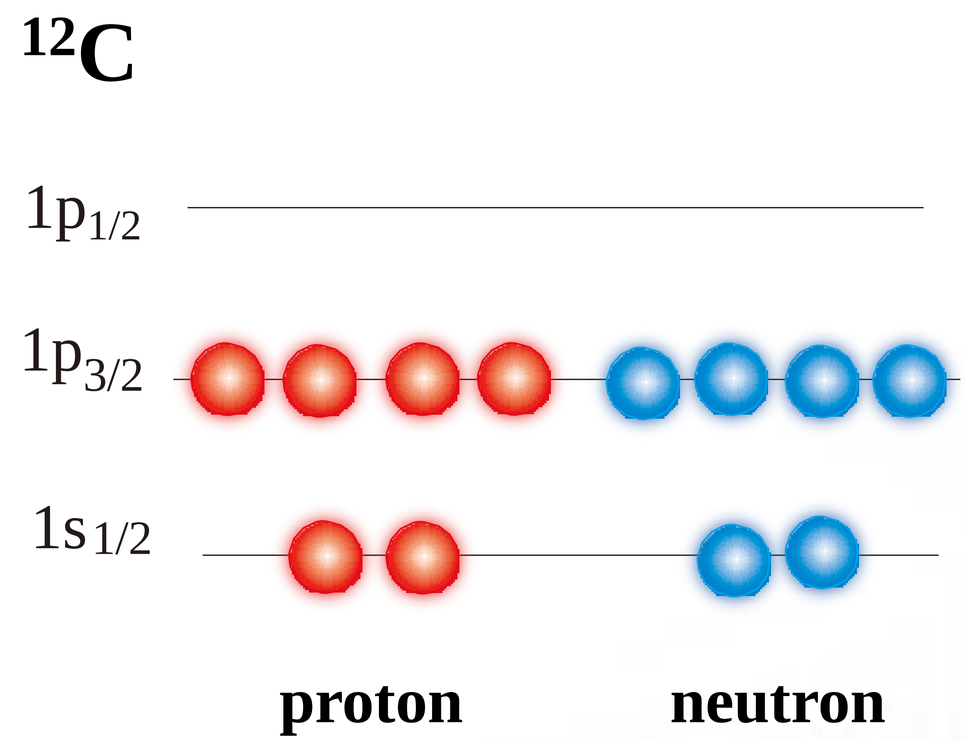


Nucleon pick-up reaction(^{12}C(p,d) &^{16}O(p,d)) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C

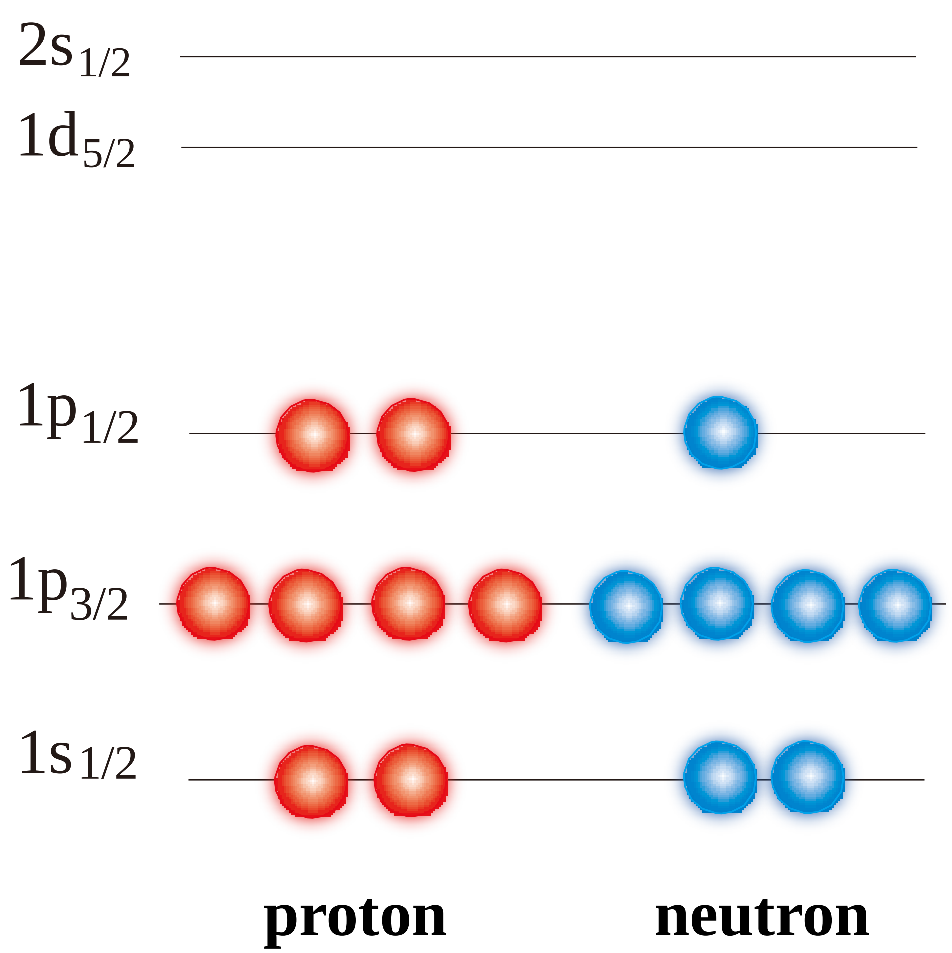




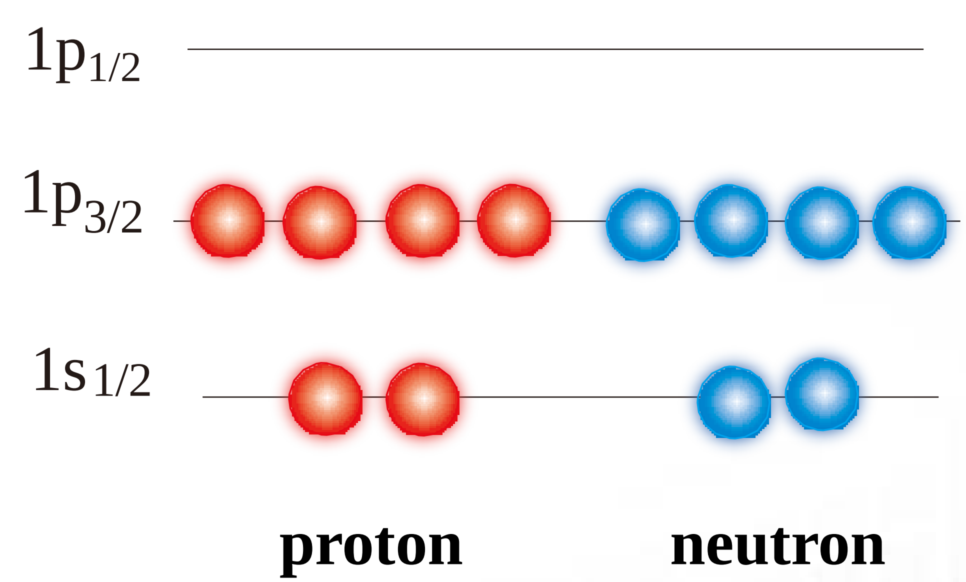
Nucleon pick-up reaction(^{12}C(p,d) & ^{16}O(p,d)) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C

^{15}O



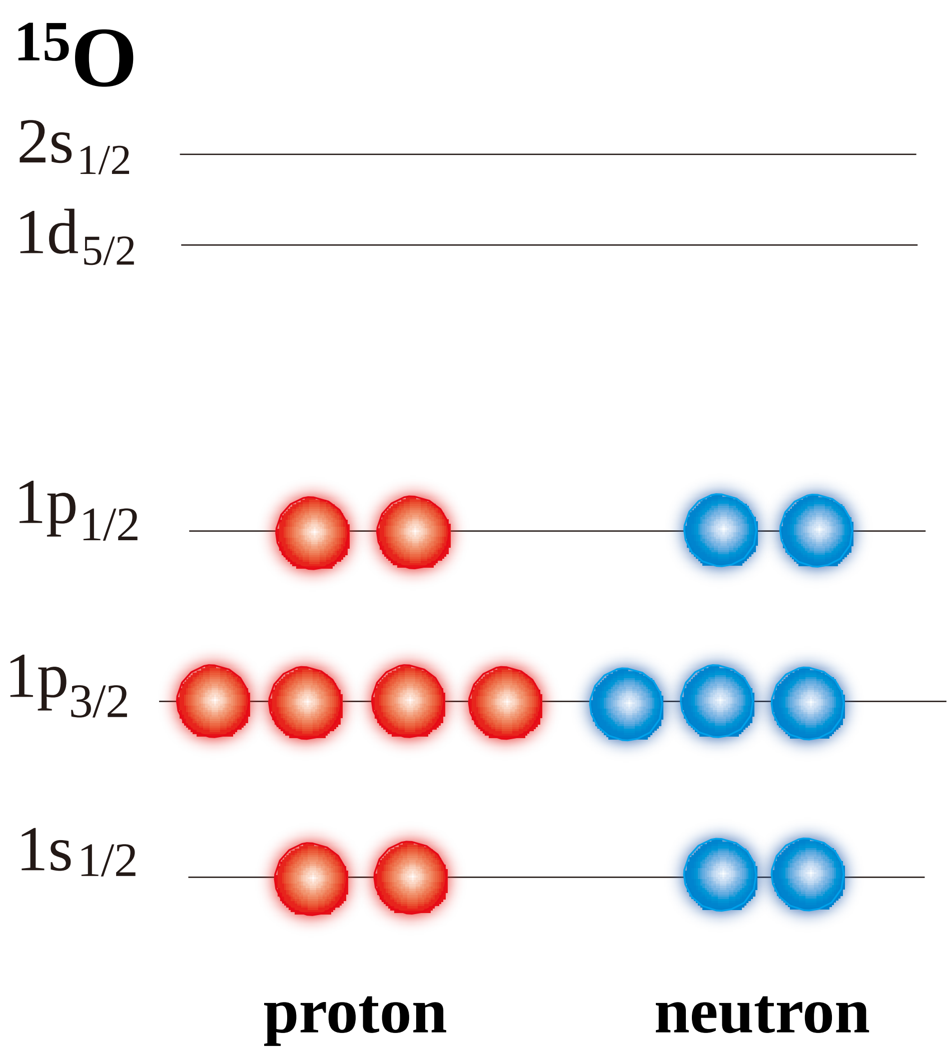
^{12}C

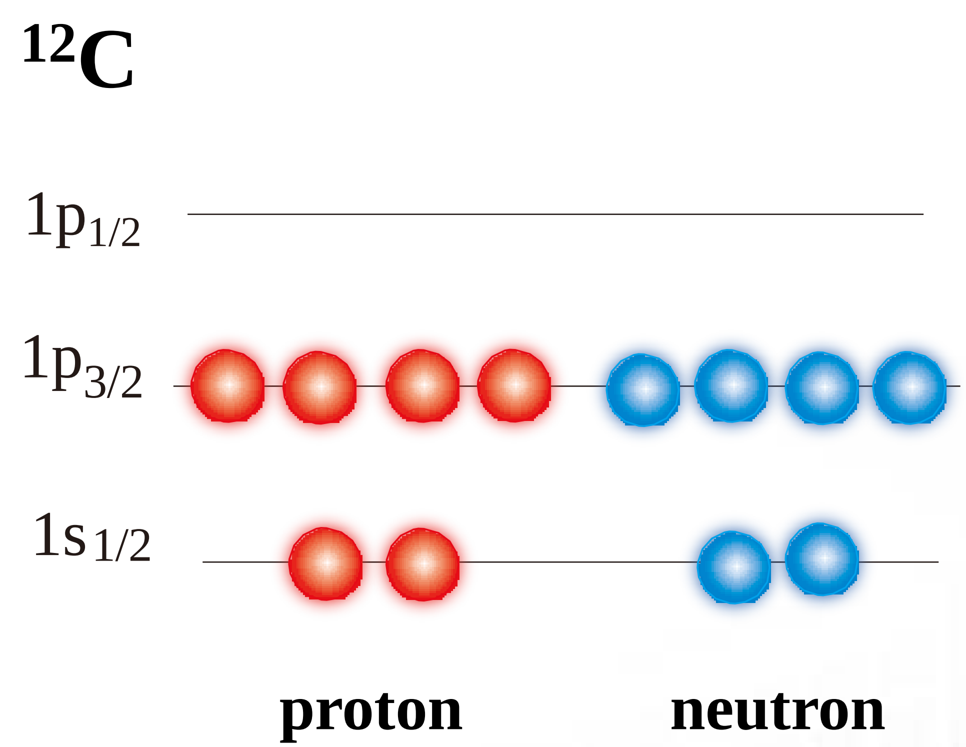


^{15}O: negative parity ground state (**J^{π}=1/2-**)

Nucleon pick-up reaction(^{12}C(p,d) & ^{16}O(p,d)) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C





^{15}O: negative parity ground state (**J^{π}=1/2-**)
negative parity excited state (**J^{π}=3/2-**)

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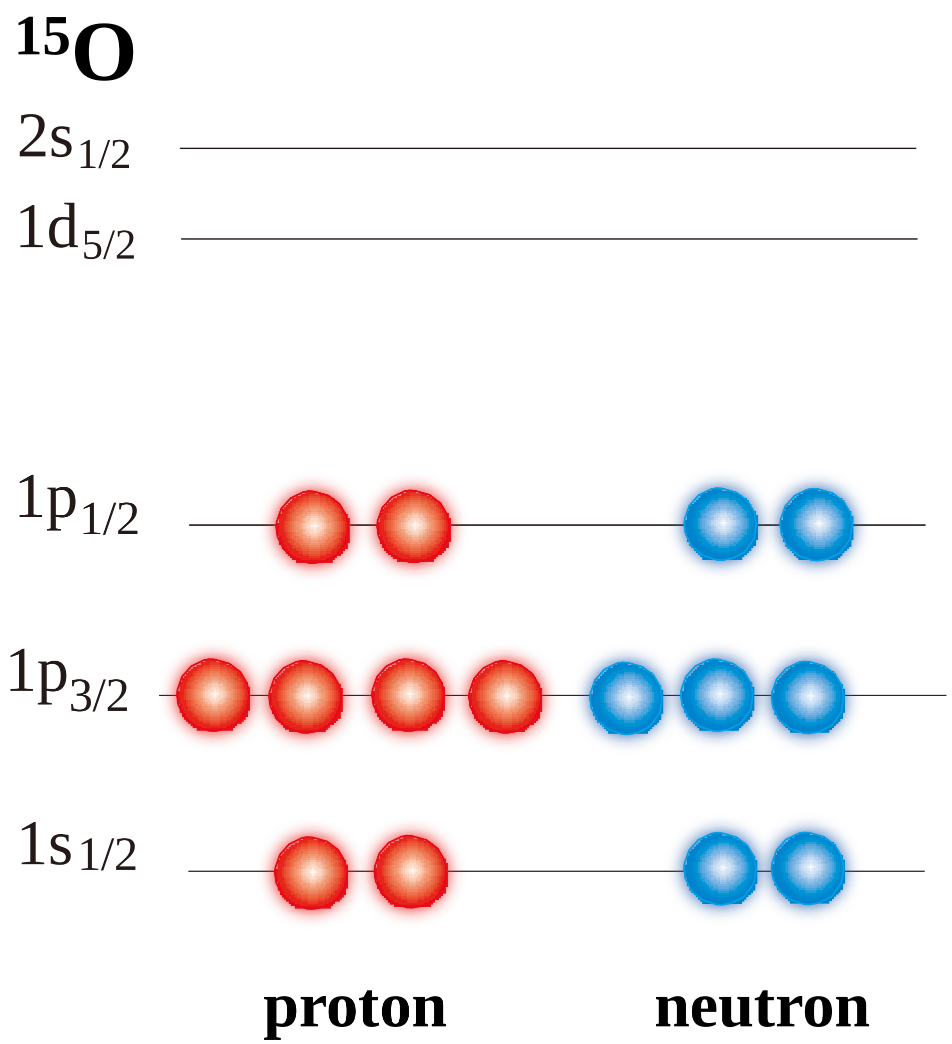
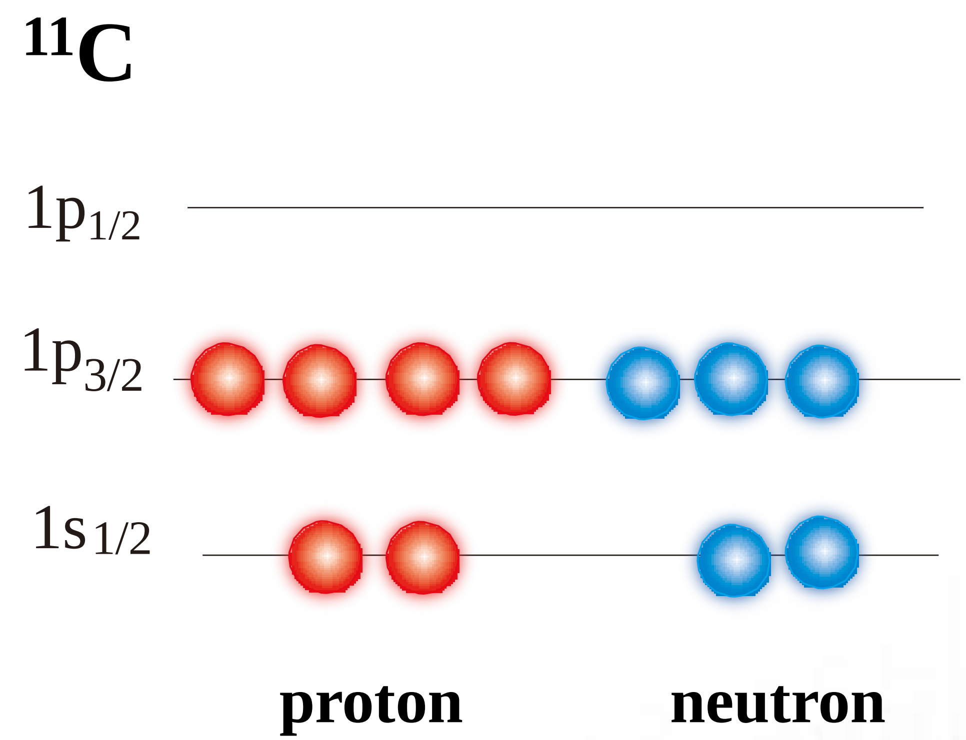


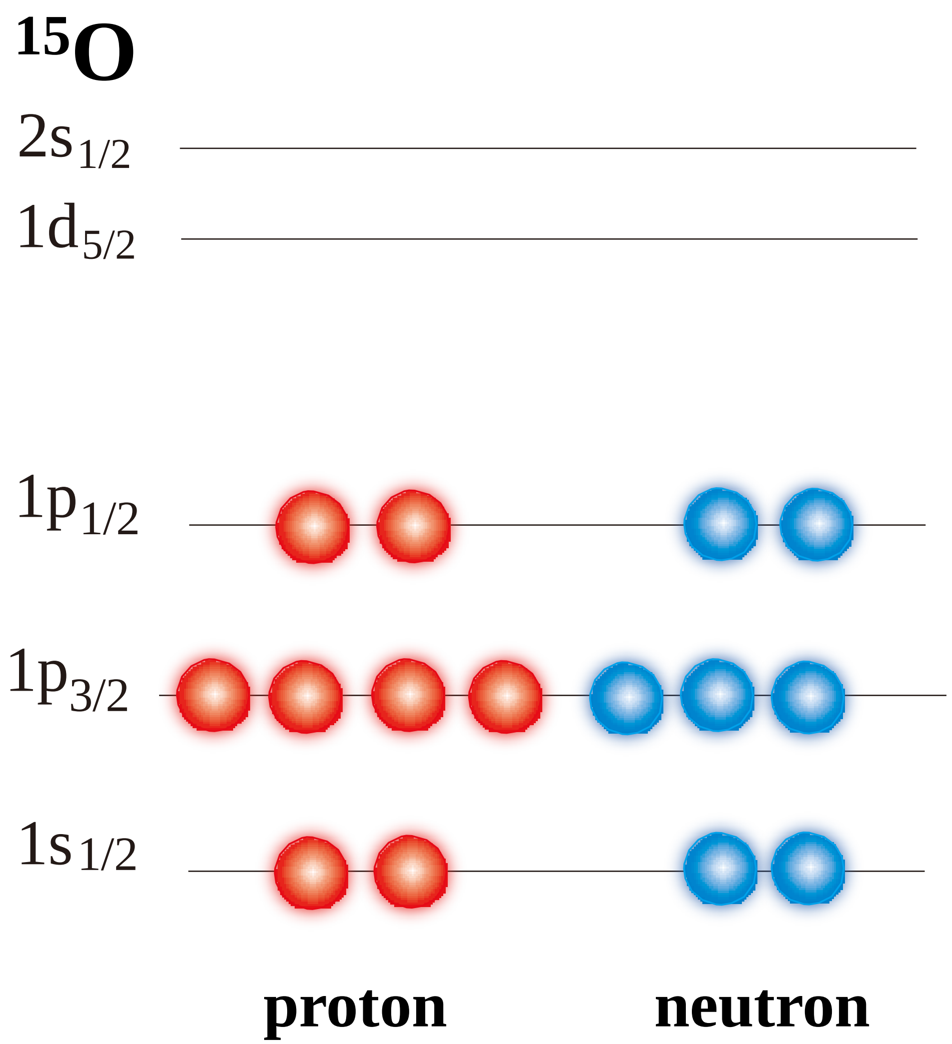


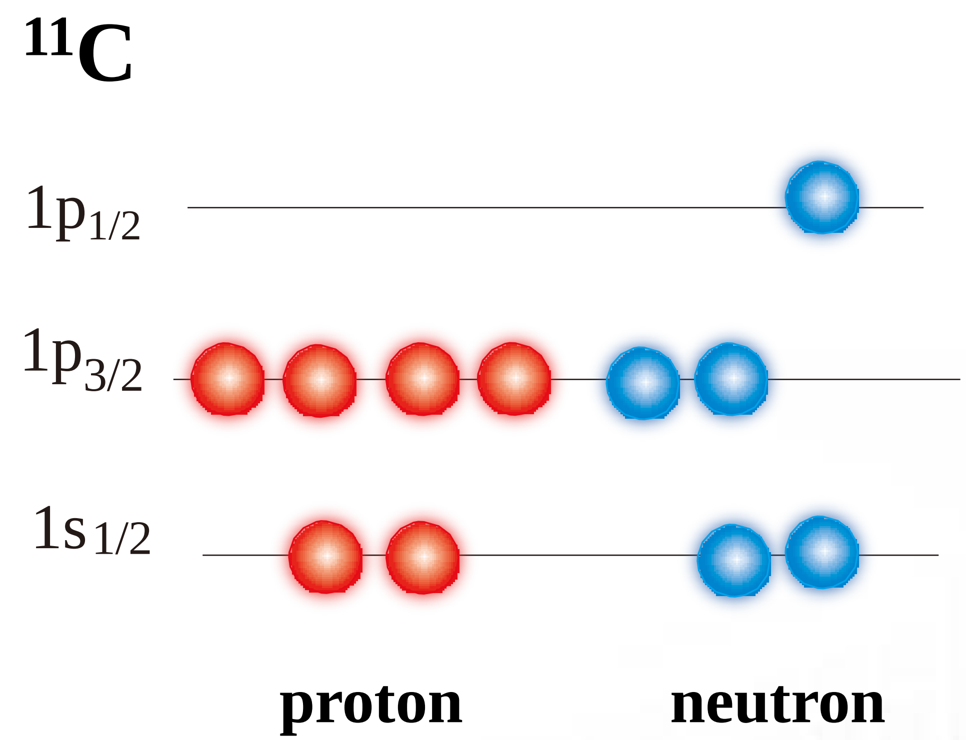
^{11}C: negative parity ground state (**J^{π}=3/2-**)

^{15}O: negative parity ground state (**J^{π}=1/2-**)
negative parity excited state (**J^{π}=3/2-**)

Nucleon pick-up reaction(^{12}C(p,d) &^{16}O(p,d)) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C





^{15}O: negative parity ground state (**J^{π}=1/2-**)
negative parity excited state (**J^{π}=3/2-**)

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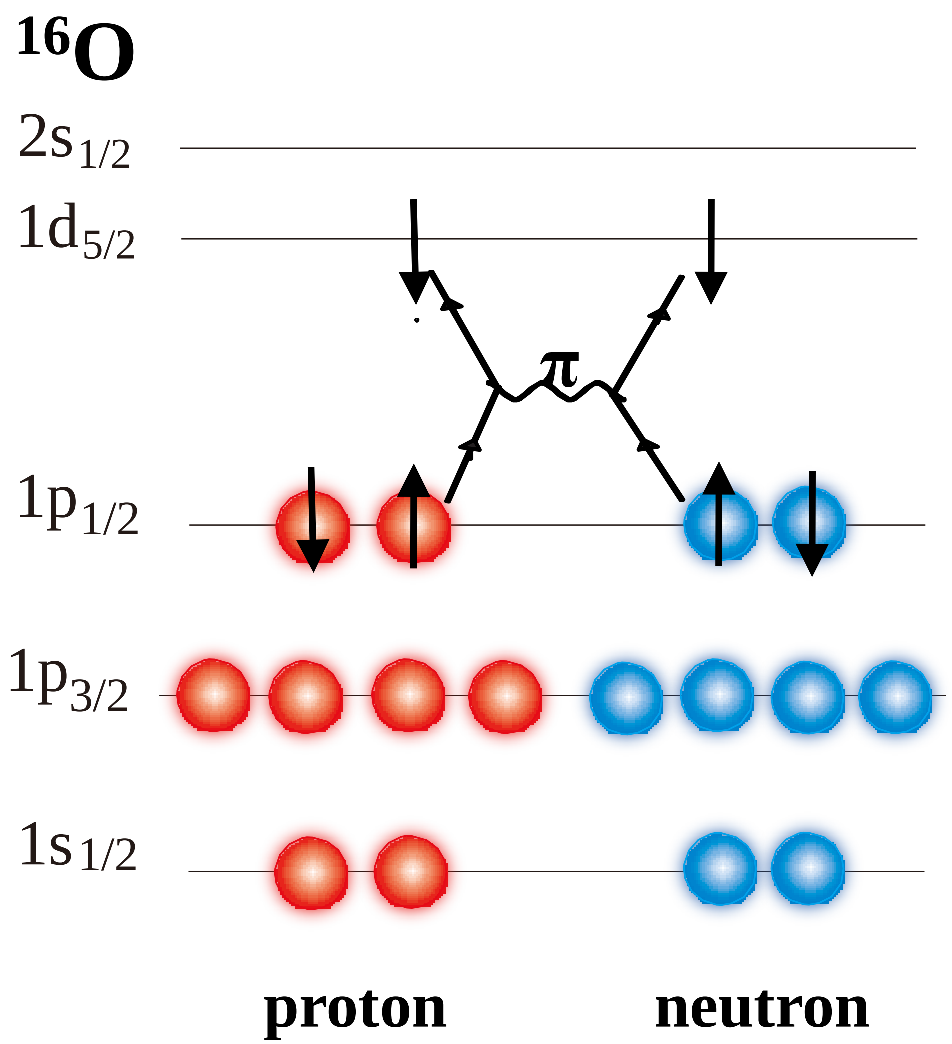
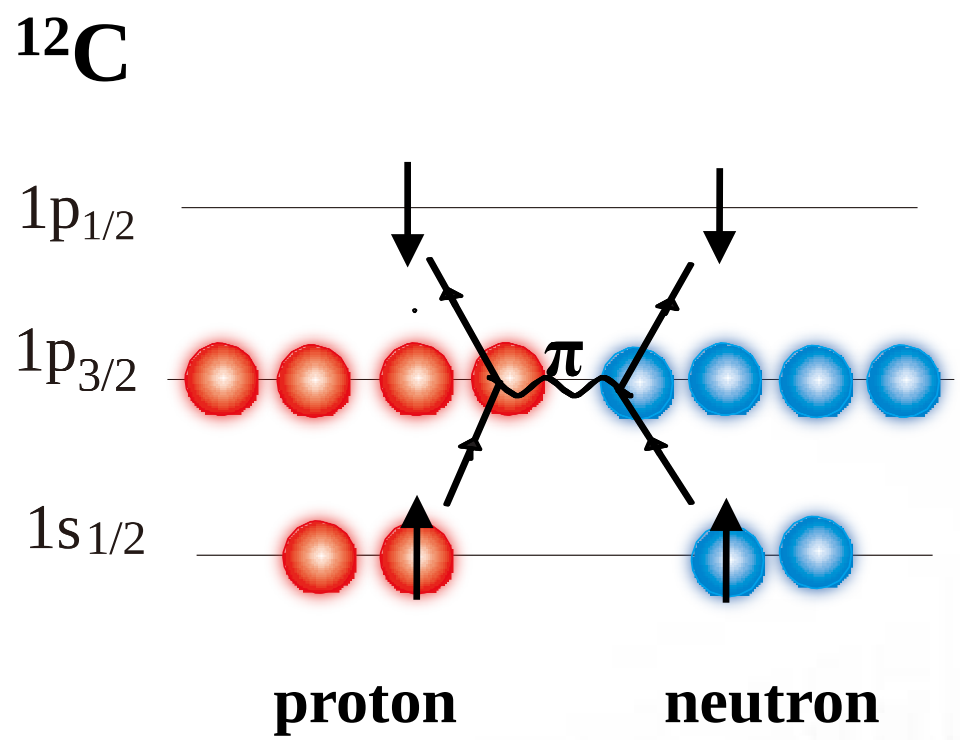
negative parity excited state (**J^{π}=1/2-**)

Nucleon pick-up reaction($^{12}C(p,d)$ & $^{16}O(p,d)$) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C

Tensor selection rule:
$\Delta L=2$, $\Delta s=2$, $\Delta J=0$





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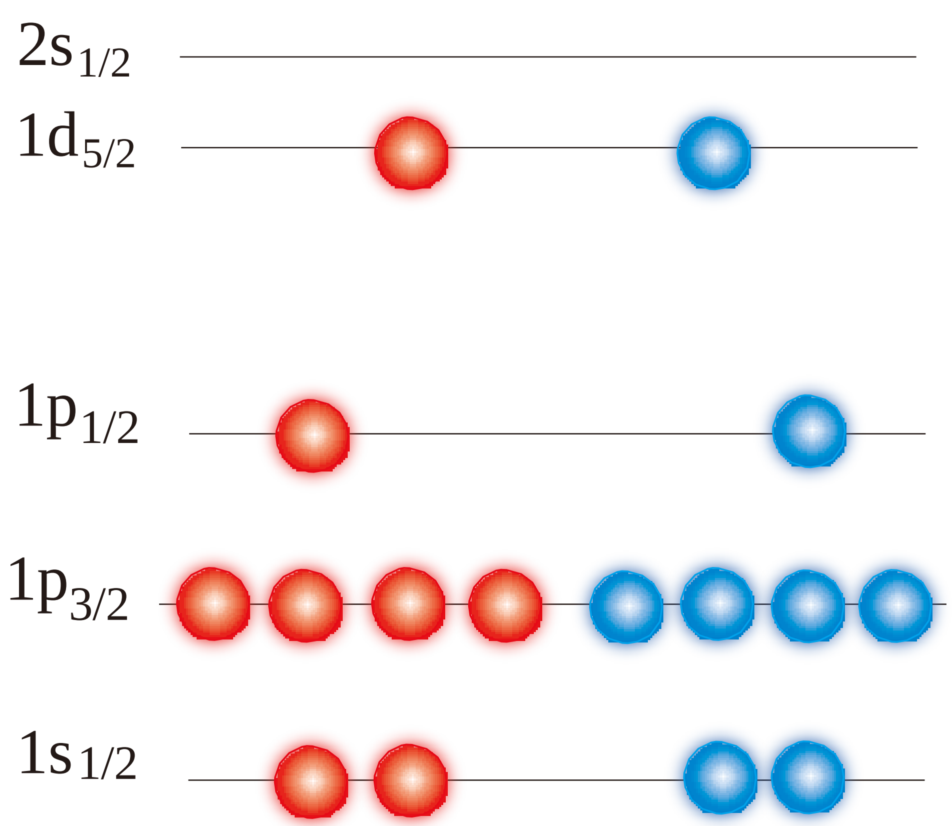
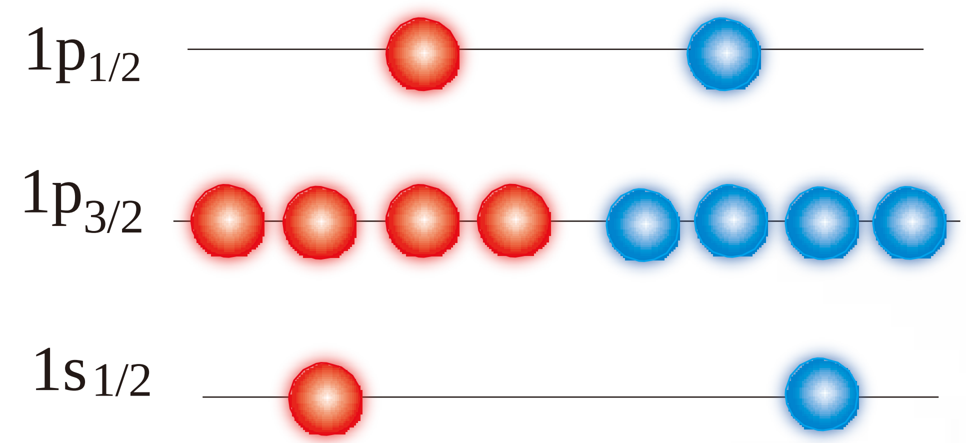
^{16}O



^{12}C



Ground state of ^{16}O ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration

Ground state of ^{12}C ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration

Nucleon pick-up reaction(^{12}C(p,d) &^{16}O(p,d)) @ RCNP, Osaka

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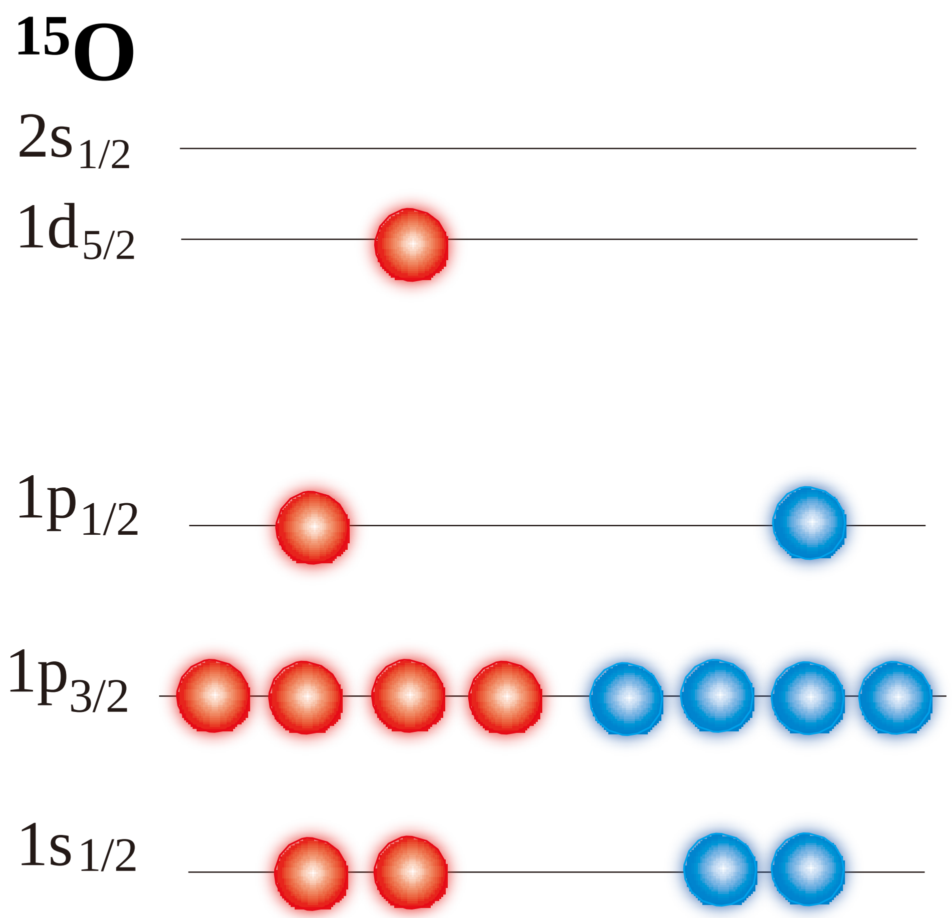
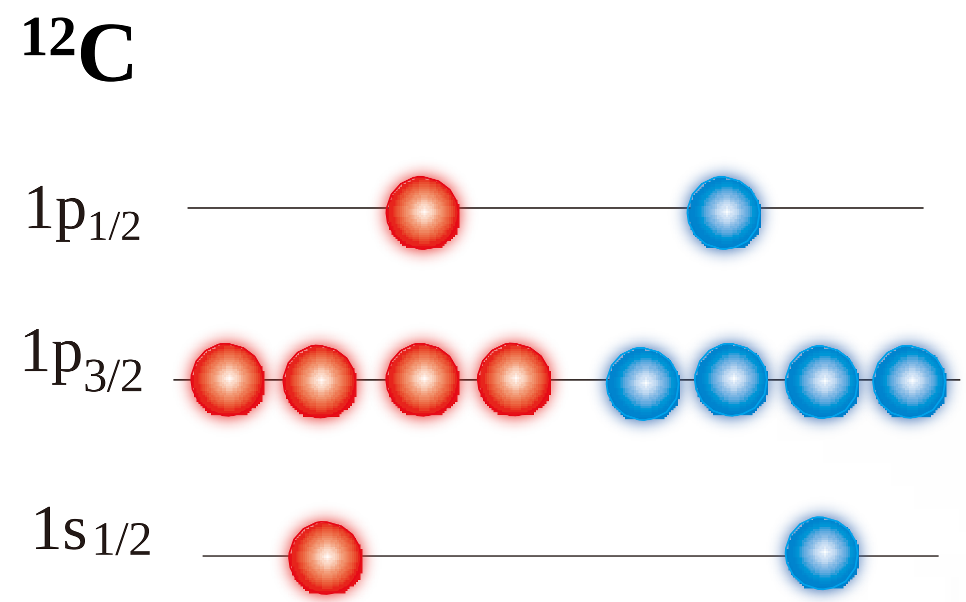
ΔL=2, Δs=2, ΔJ=0





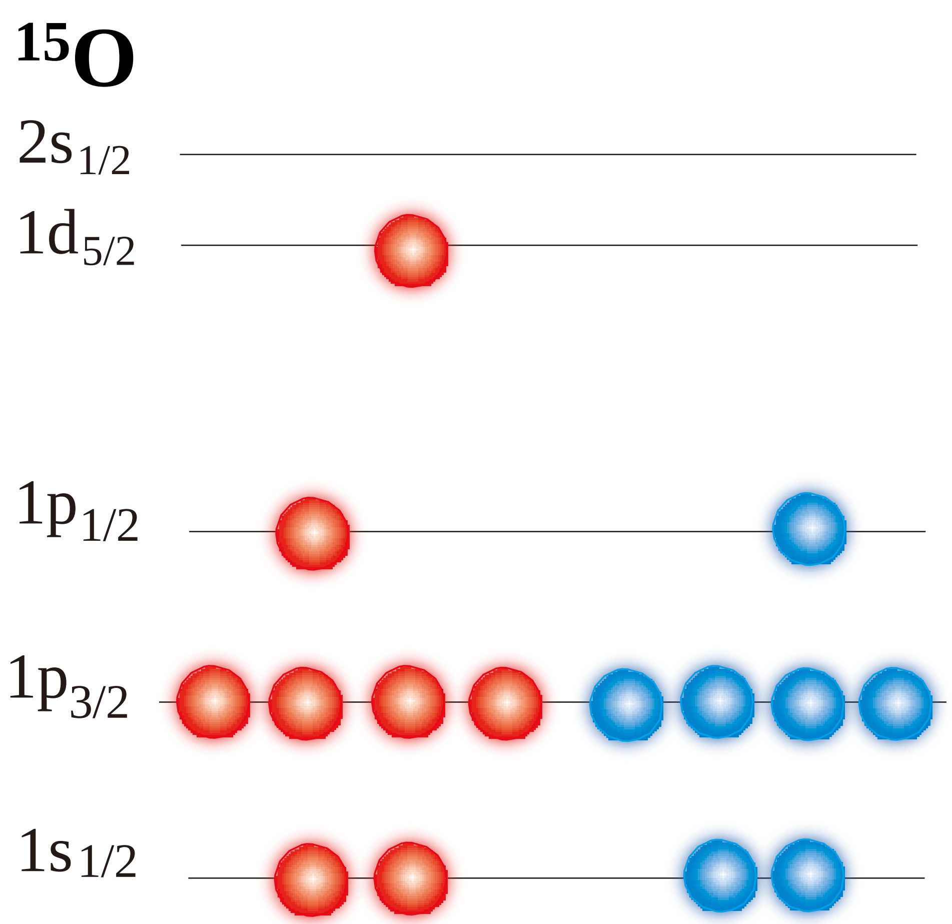
Ground state of ^{16}O ($J^\pi=0^+$):
mixing of 2p-2h configuration
→ ^{15}O: positive parity excited state (**J^π=5/2+**)

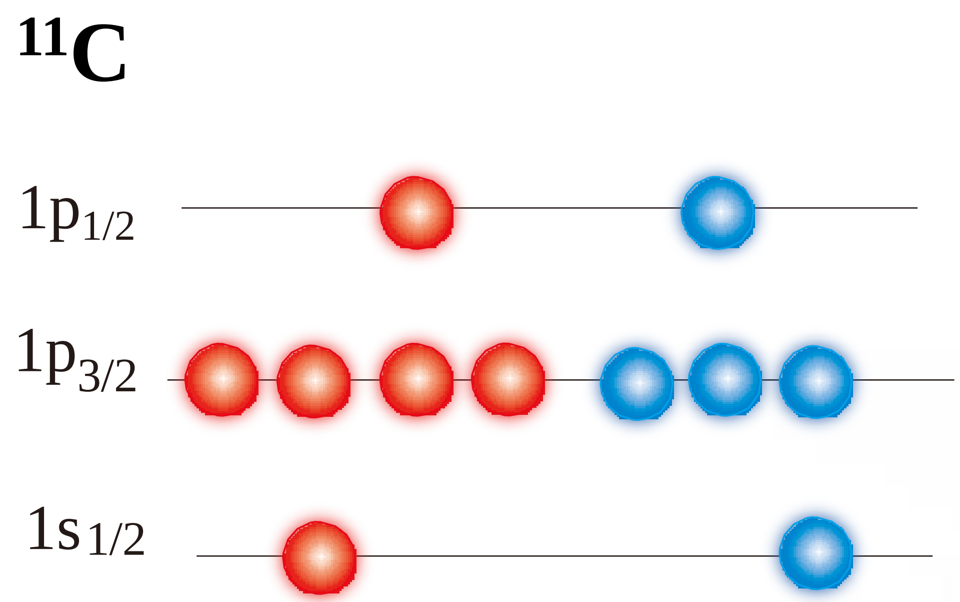
Ground state of ^{12}C ($J^\pi=0^+$):
mixing of 2p-2h configuration

Nucleon pick-up reaction($^{12}C(p,d)$ & $^{16}O(p,d)$) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C

Tensor selection rule:
$\Delta L=2$, $\Delta s=2$, $\Delta J=0$





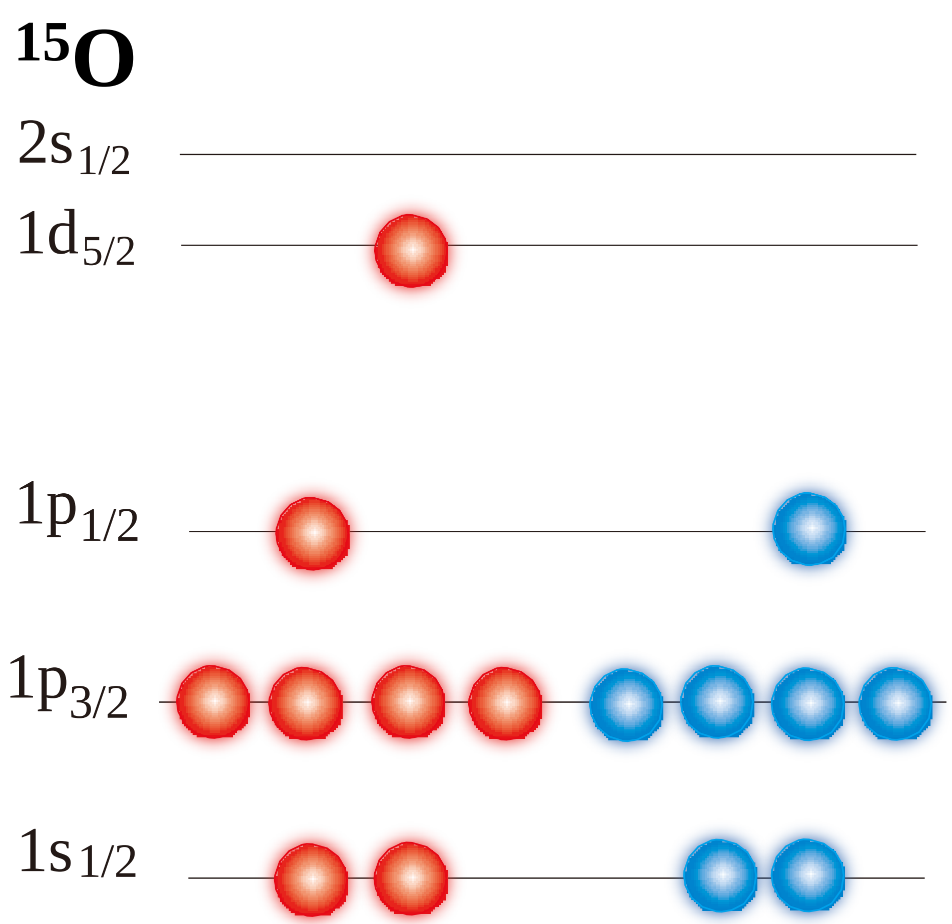
Ground state of ^{16}O ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration
→ ^{15}O: positive parity excited state (**$J^{\pi}=5/2+$**)

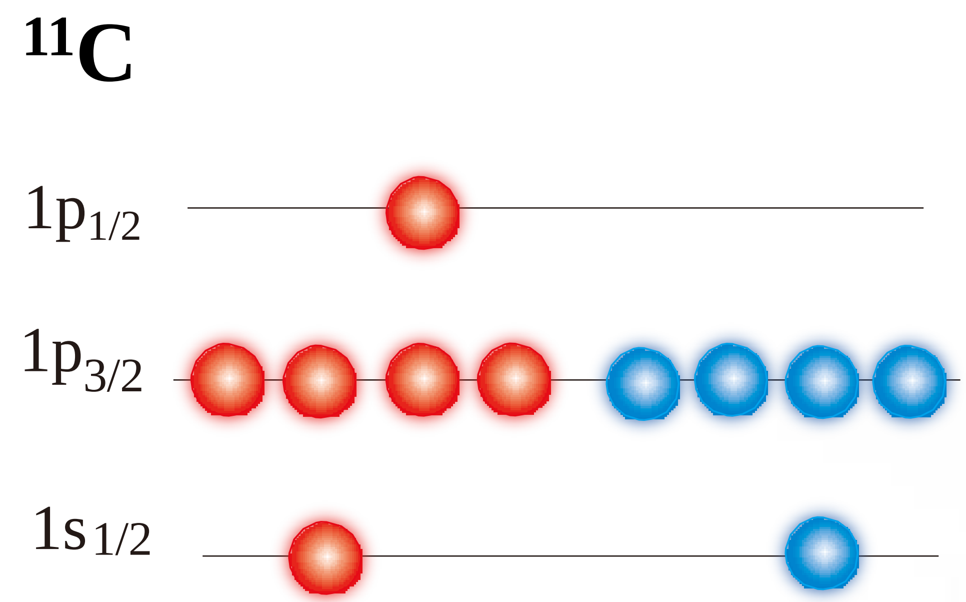
Ground state of ^{12}C ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration
→ ^{11}C: ground state (**$J^{\pi}=3/2-$**)

Nucleon pick-up reaction(^{12}C(p,d) &^{16}O(p,d)) @ RCNP, Osaka

Configuration difference for ^{16}O & ^{12}C

Tensor selection rule:
ΔL=2, Δs=2, ΔJ=0



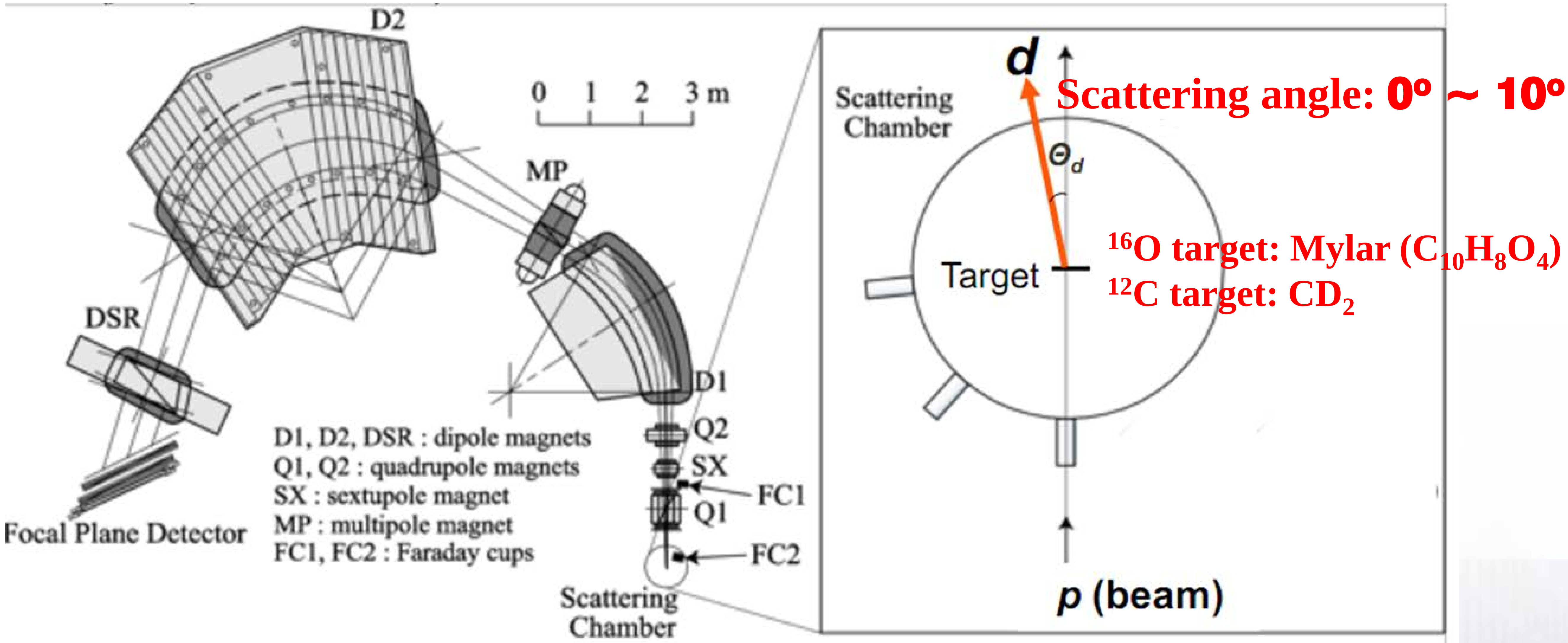


Ground state of ^{16}O ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration
→ ^{15}O: positive parity excited state (**J^{π}=5/2+**)

Ground state of ^{12}C ($J^{\pi}=0^{+}$):
mixing of 2p-2h configuration
→ ^{11}C: ground state (**J^{π}=3/2-**)
excited state (**J^{π}=1/2-**)

Nucleon pick-up reaction($^{12}C(p,d)$ & $^{16}O(p,d)$) @ RCNP, Osaka

Grand RAIDEN Spectrometer $p/\Delta p$~37000



Focal Plane Detector:
Two Plastic scintillator for ΔE & TOF
Two VDCs (drift chamber) for position and angle (x,dx,y,dy)

Beam energy: 392 MeV/nucleon
Beam Intensity: 10 nA
Energy resolution ≤ 150keV (Achromatic mode)

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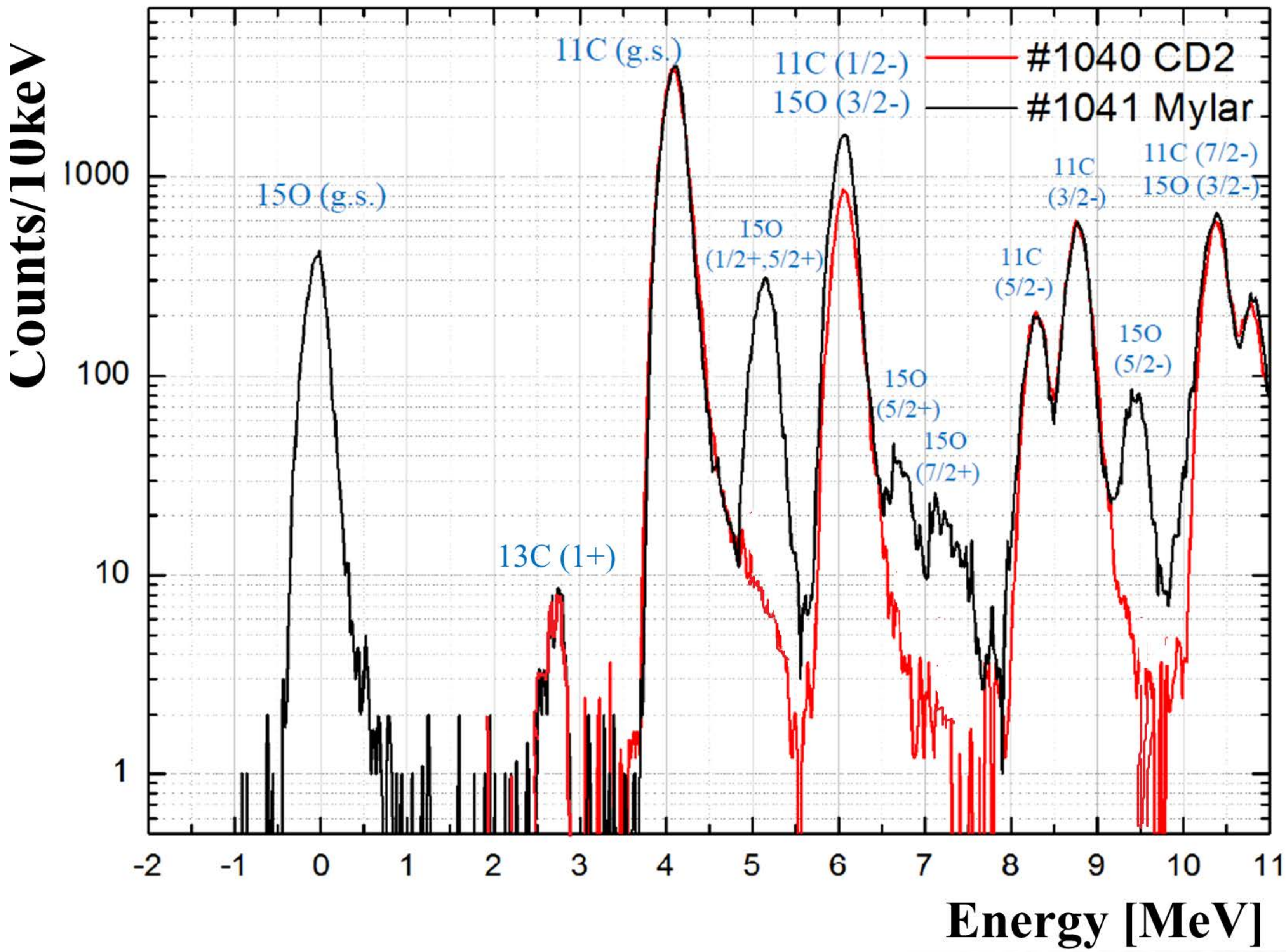

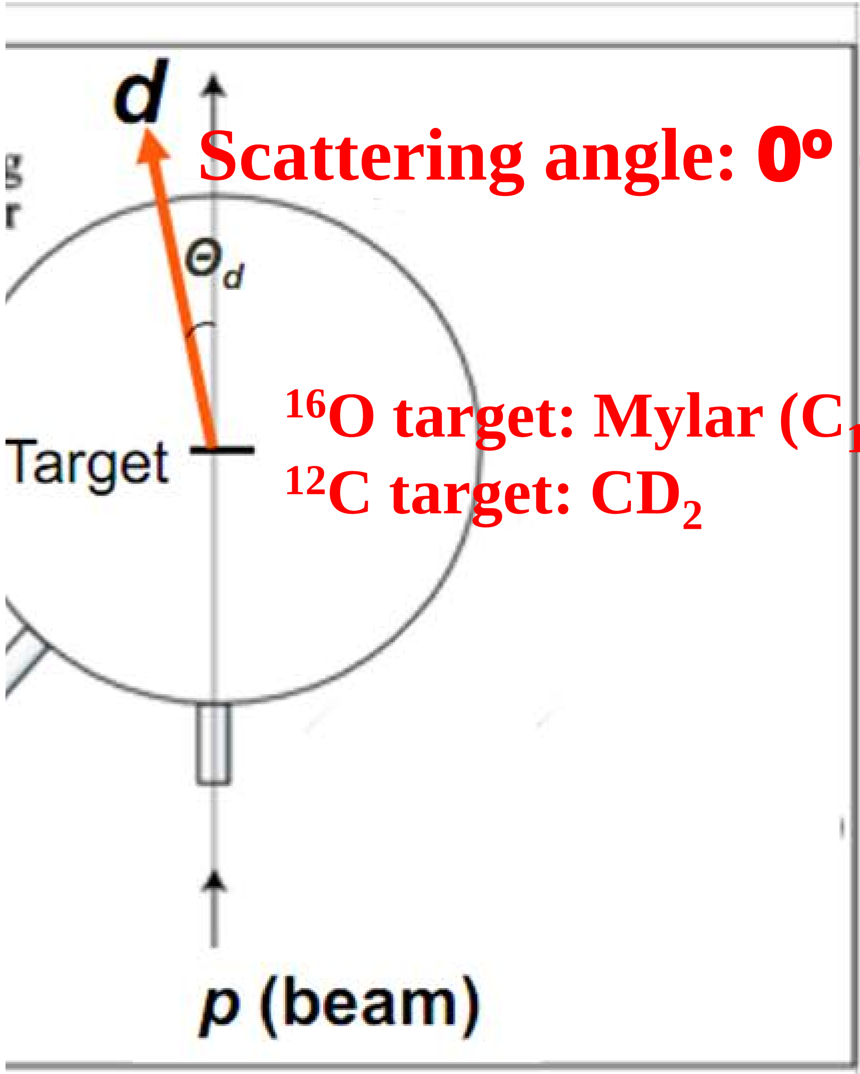

Scattering angle: 0° ~ 10°

^{16}O target: Mylar ($C_{10}H_8O_4$)
^{12}C target: CD_2

Focal Plane Detector:
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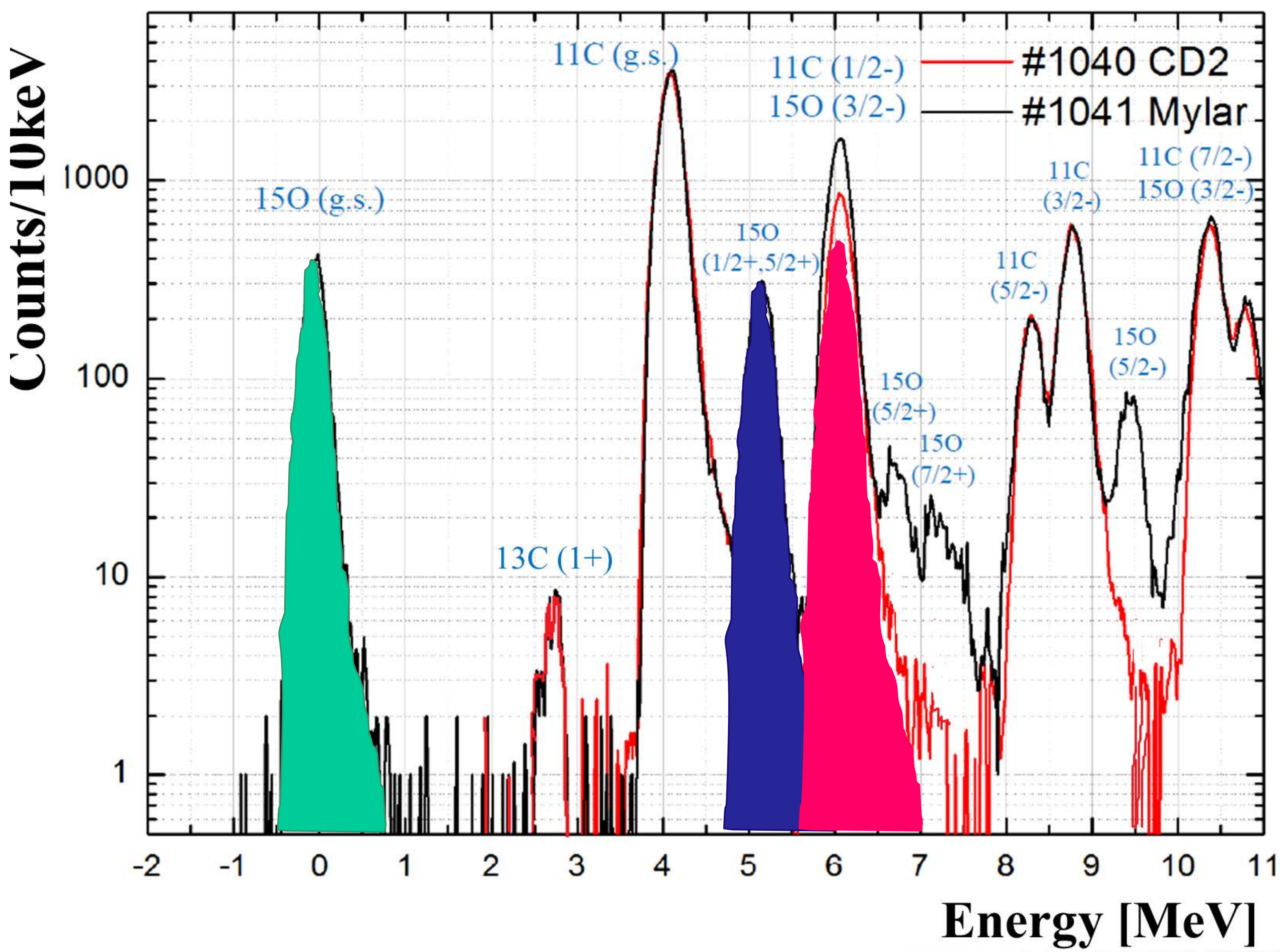

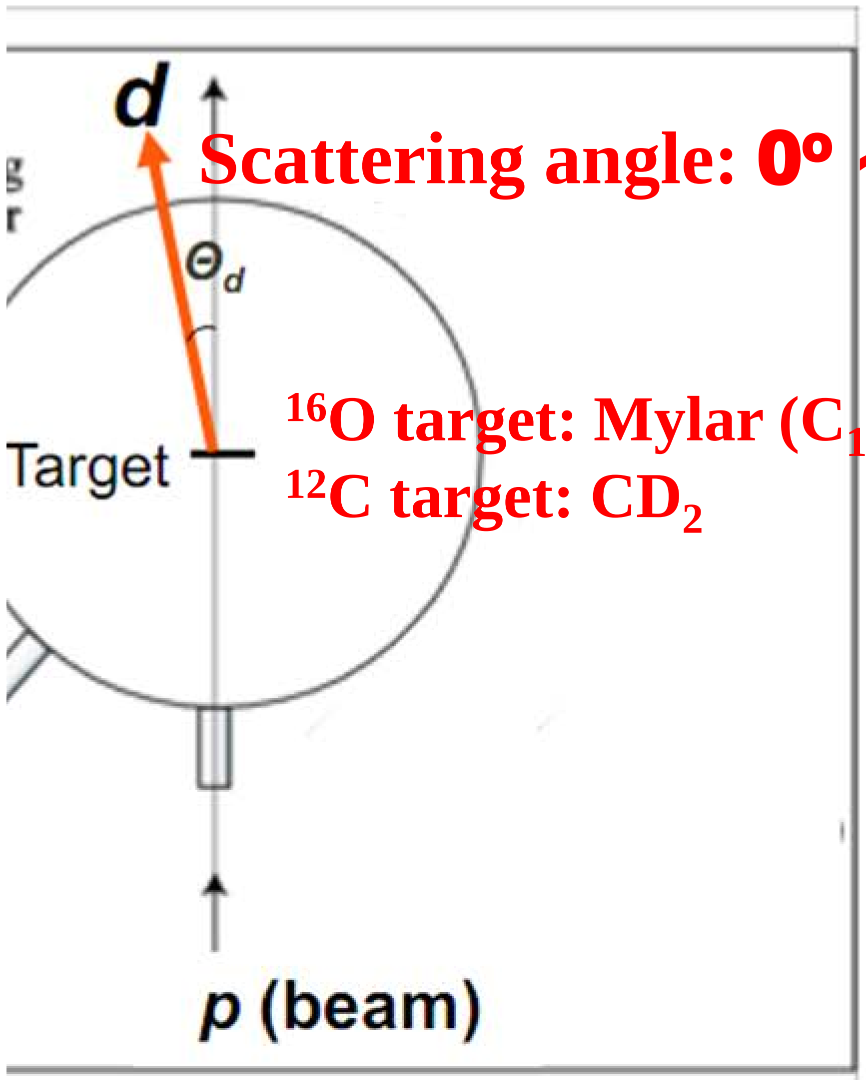

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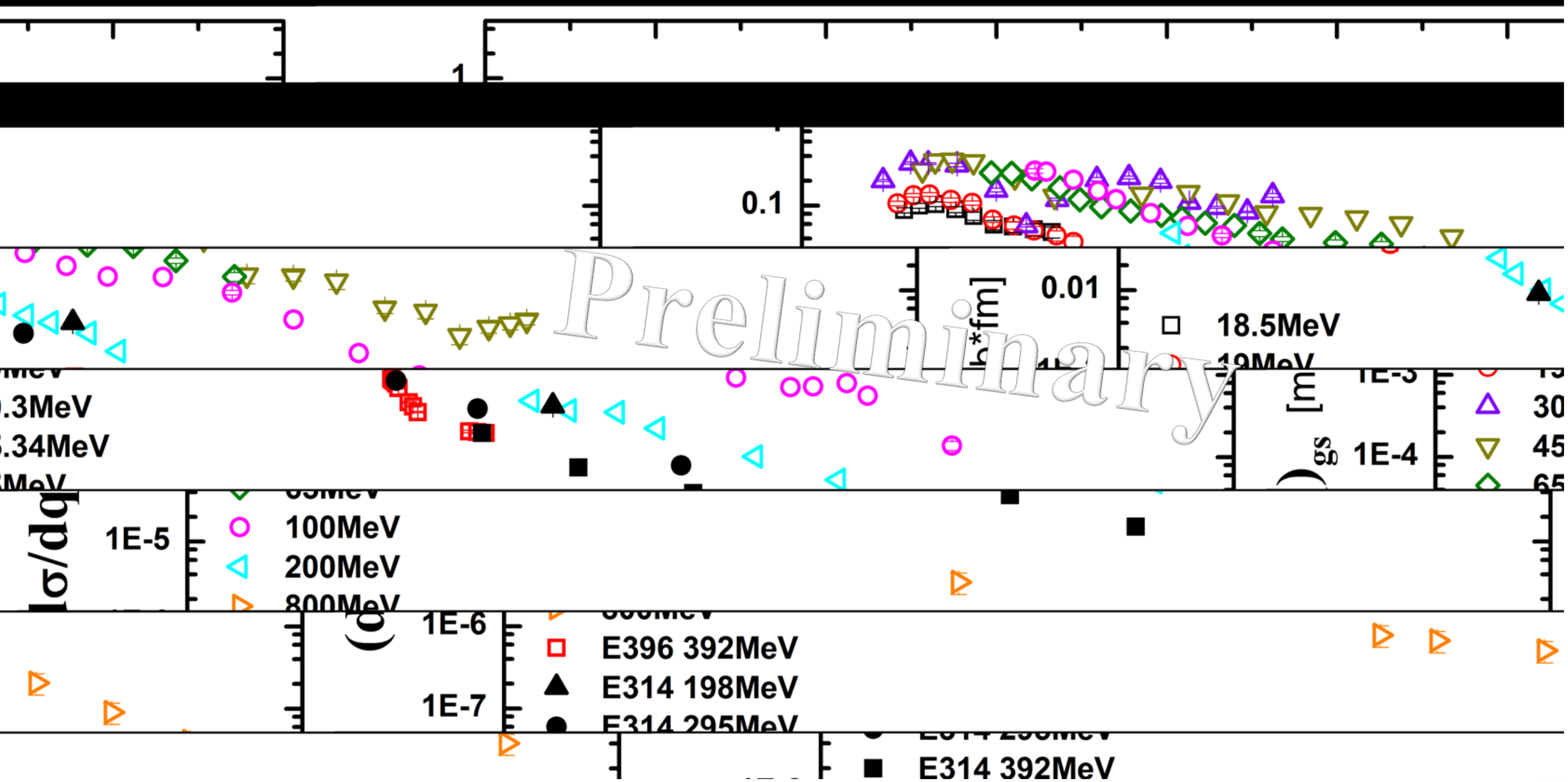
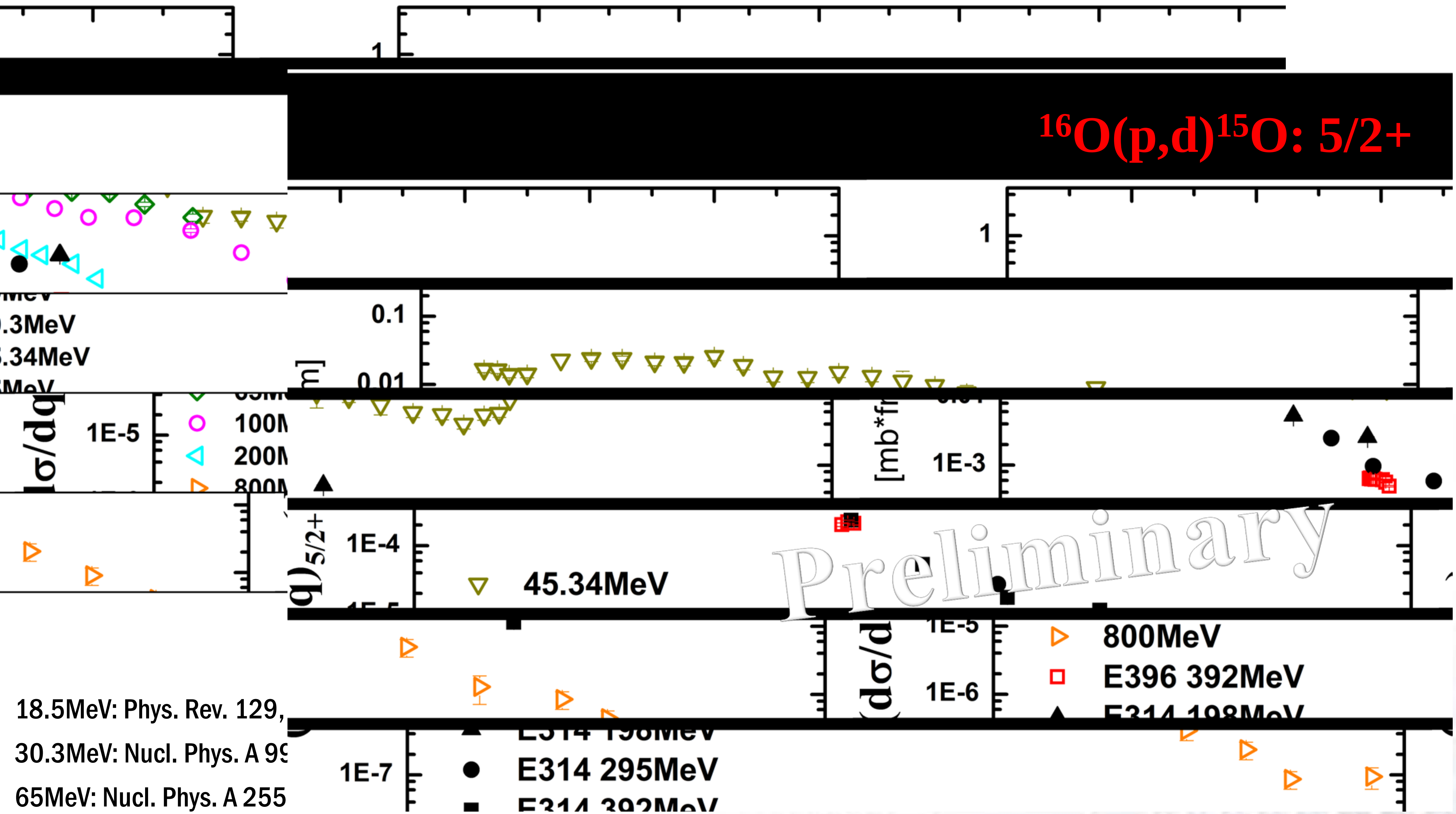
$^{16}O(p,d)^{15}O$: 1/2-



18.5MeV: Phys. Rev. 129, 272 (1963)
19MeV: Phys. Rev. 129, 272 (1963)
30.3MeV: Nucl. Phys. A 99, 669 (1967)
45MeV: Phys. Rev. 187, 1246 (1969)
65MeV: Nucl. Phys. A 255, 187 (1975)
100MeV: Nucl. Phys. A 106, 357 (1968)
200MeV: Phys. Rev. C 39, 65 (1989)
800MeV: Phys. Rev. C 30, 593 (1984)
E314 198MeV & 295MeV & 392MeV: Phys. Lett. B 725, 277 (2013)

$^{16}O(p,d)^{15}O$: 1/2-

$^{16}O(p,d)^{15}O$: 5/2+



18.5MeV: Phys. Rev. 129,

30.3MeV: Nucl. Phys. A 9

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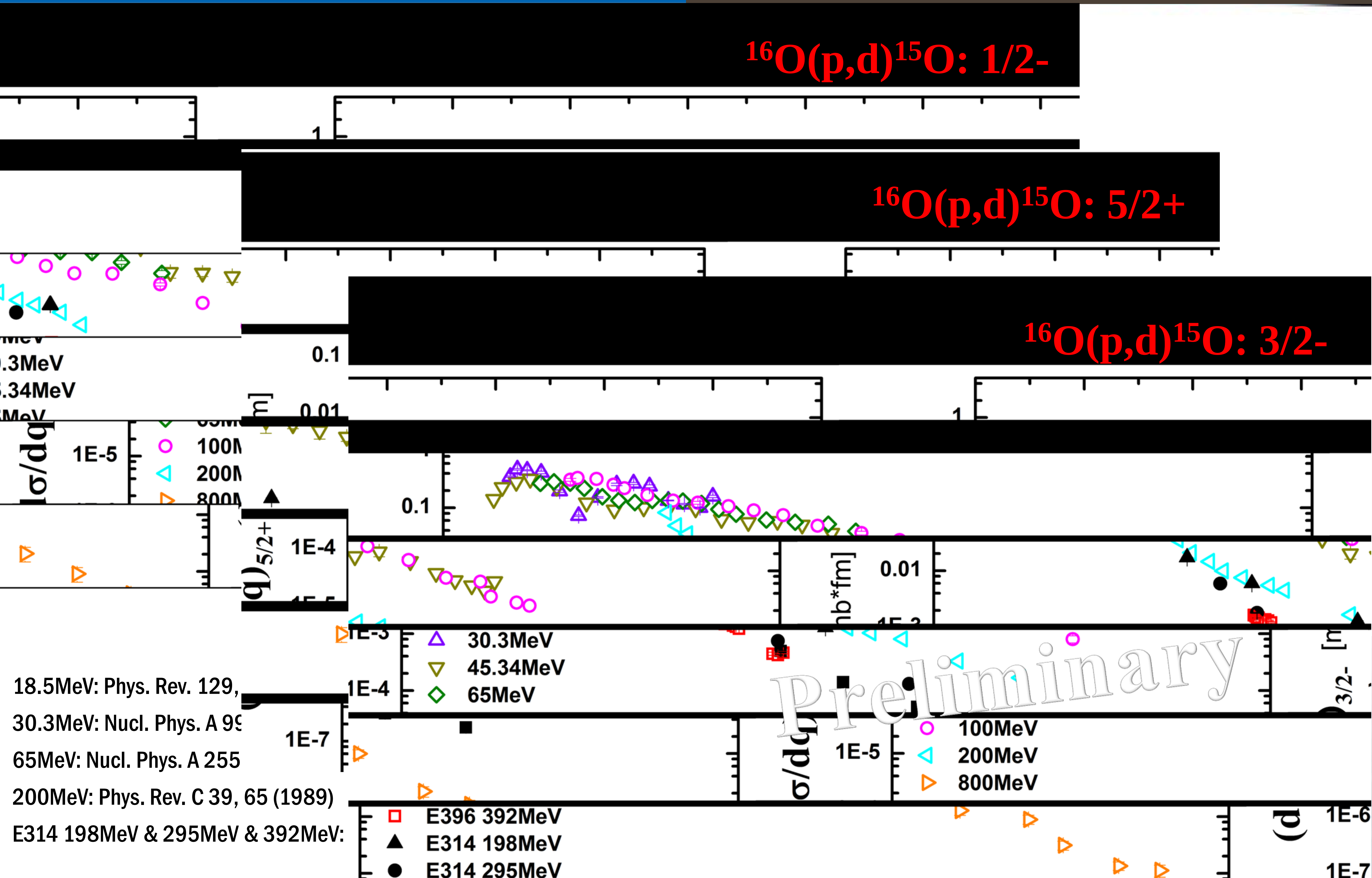

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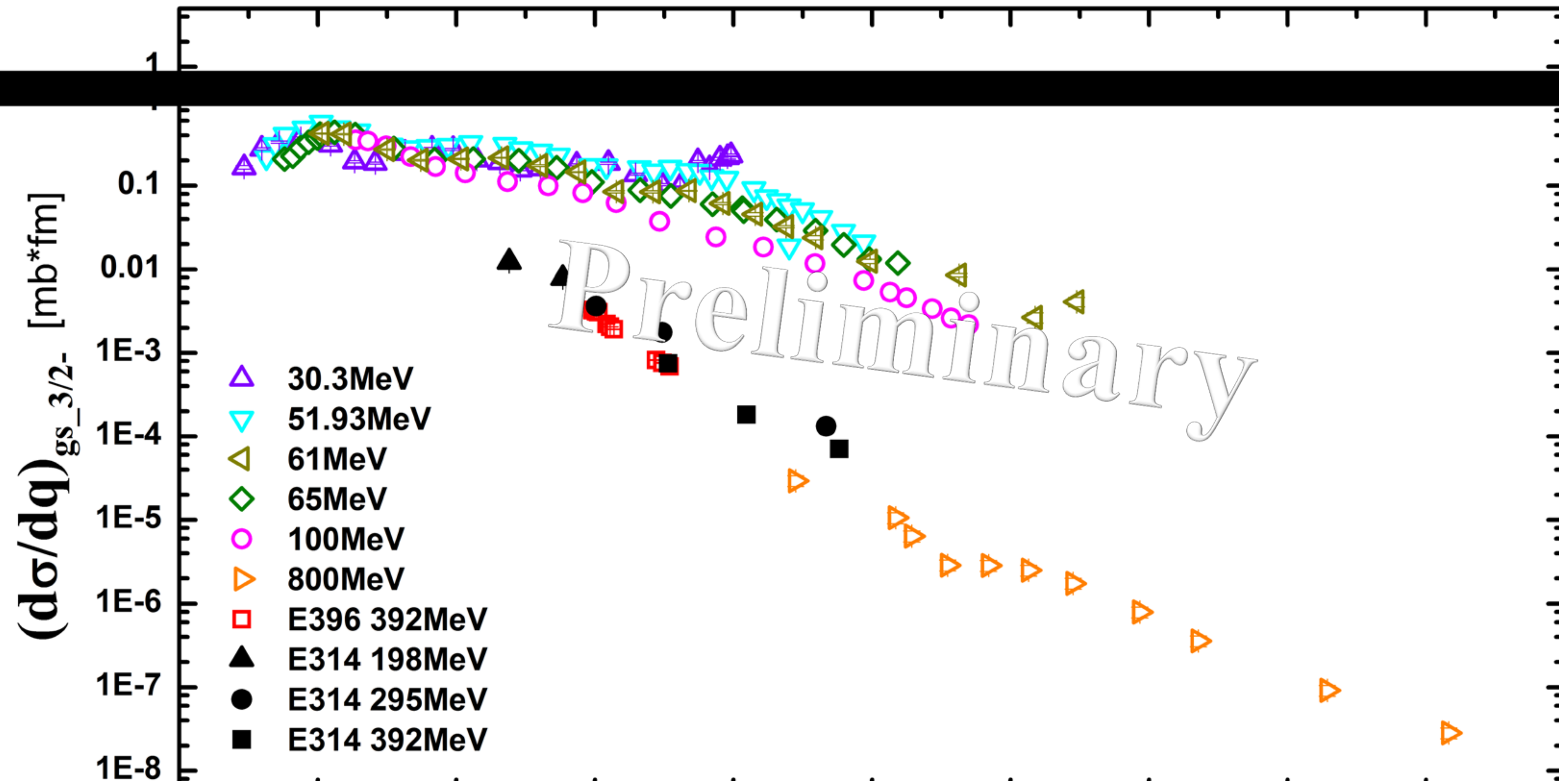
200MeV: Phys. Rev. C 39, 65 (1989)
E314 198MeV & 295MeV & 392MeV:

$^{12}C(p,d)^{11}C$: 3/2-



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61MeV: Phys. Rev. C 8,1045 (1973)

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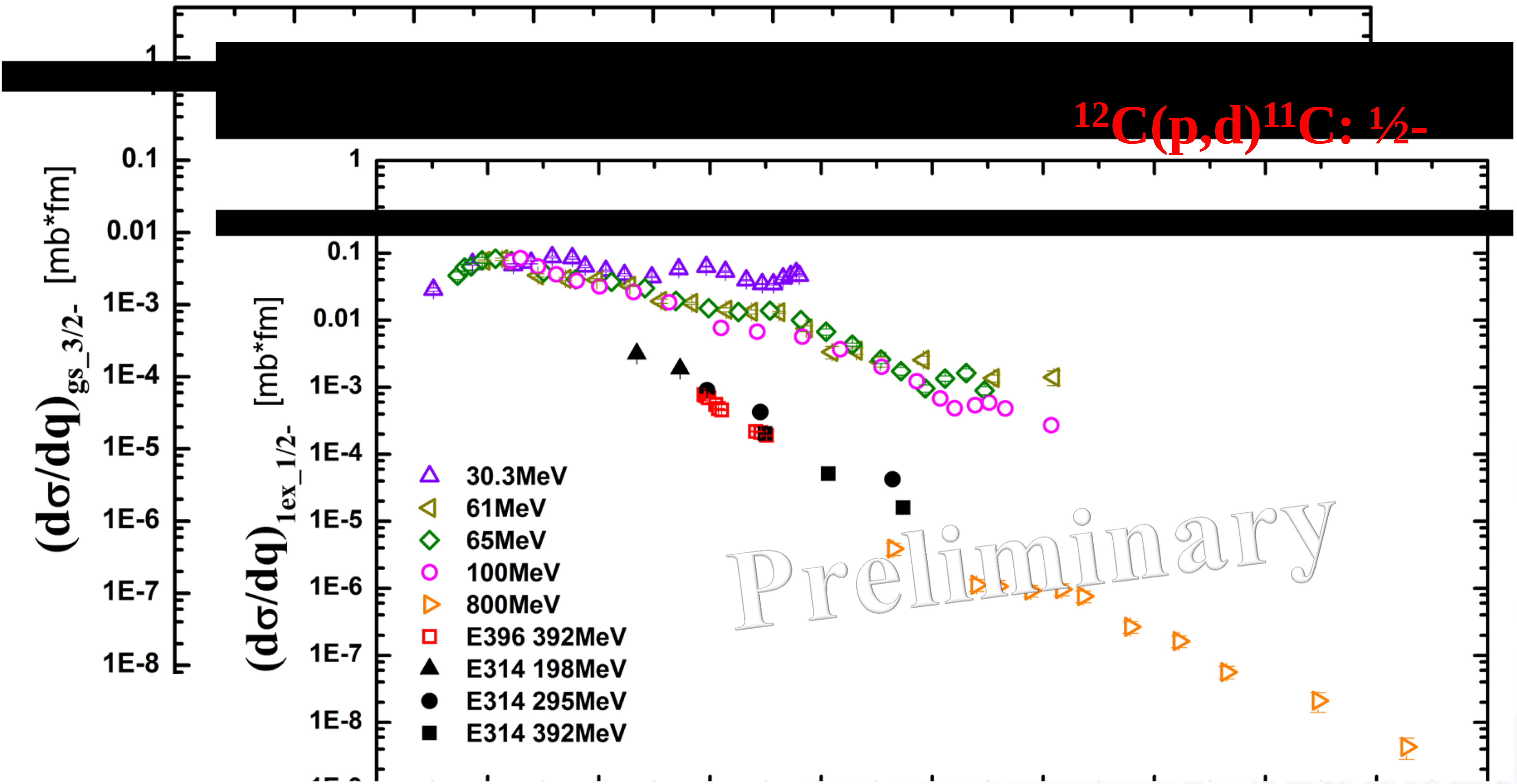
E314 198MeV & 295MeV & 392MeV: Phys. Lett. B 725, 277 (2013)

[redacted] $^{12}C(p,d)^{11}C$: 3/2-



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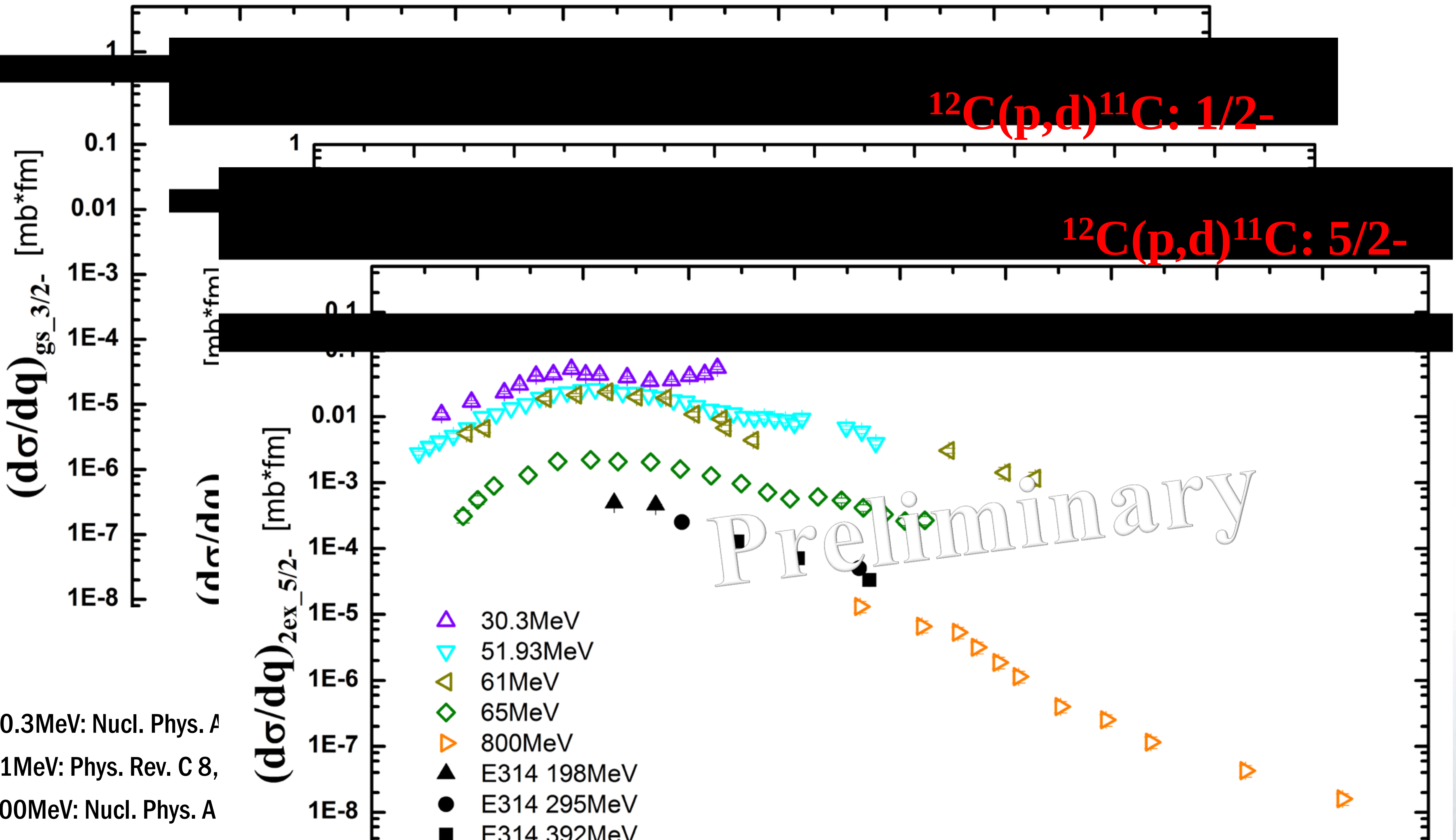
[redacted] $^{12}C(p,d)^{11}C$: 1/2-

[redacted] $^{12}C(p,d)^{11}C$: 5/2-



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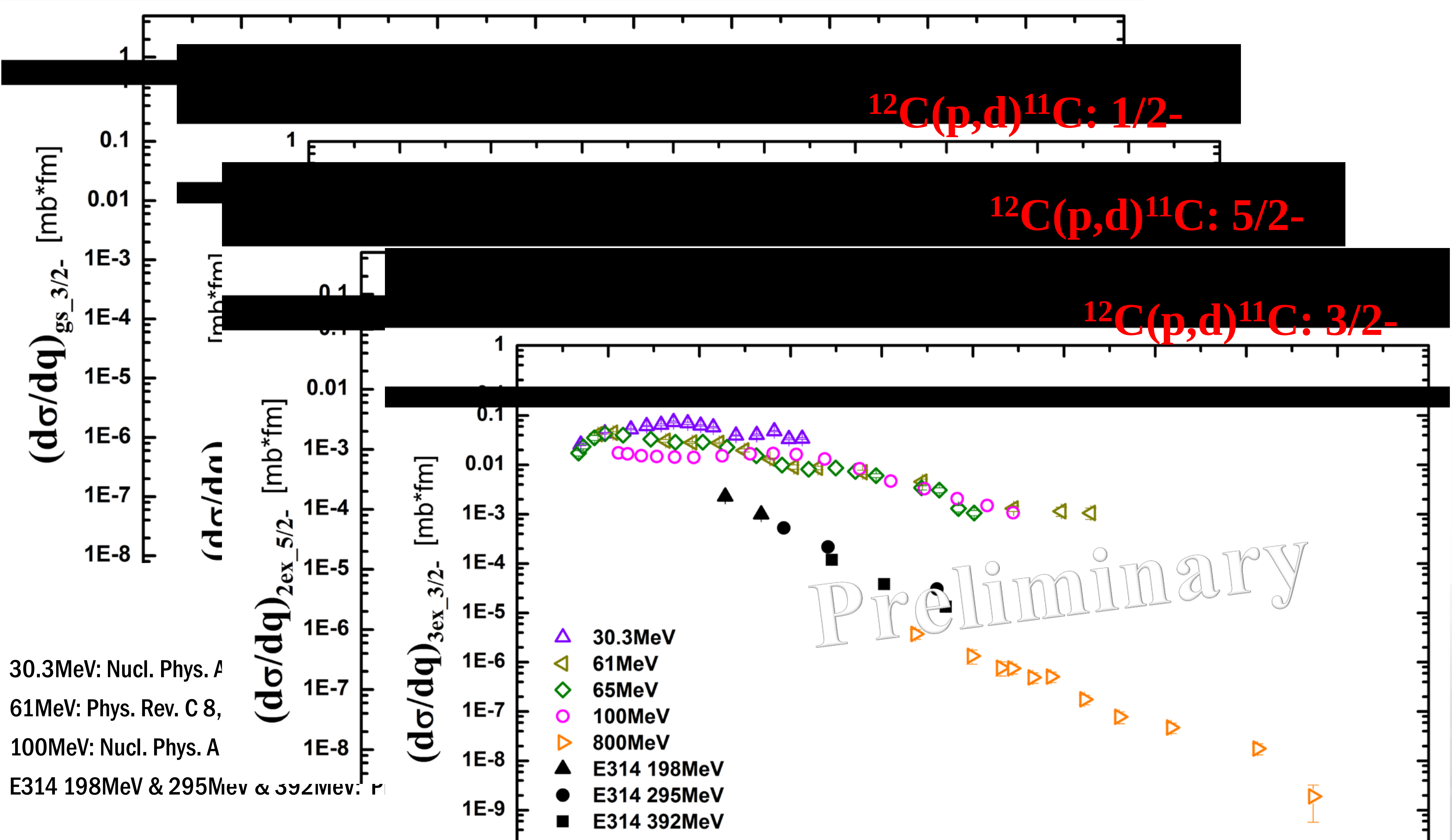

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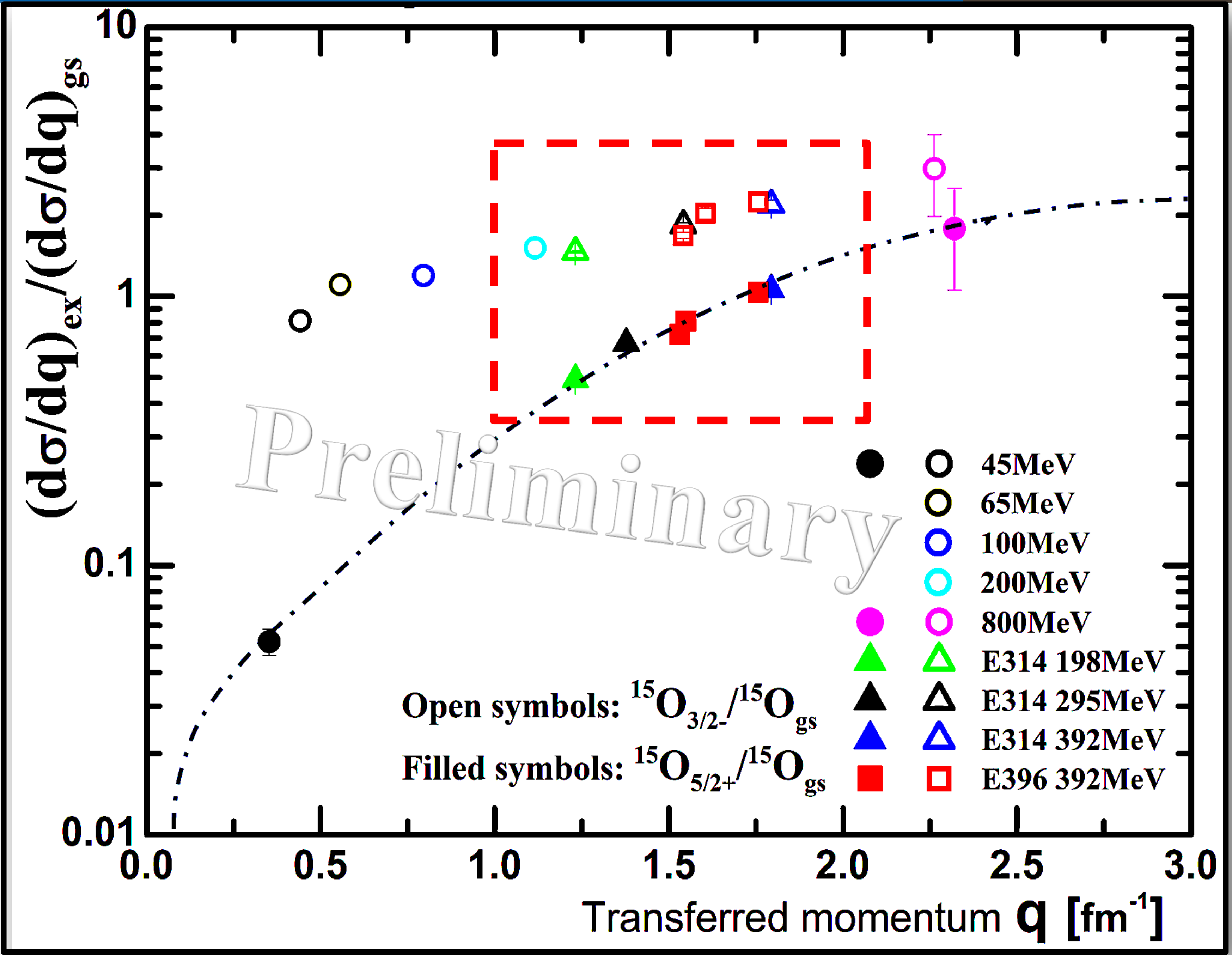
E314 198MeV & 295MeV & 392MeV: P



As long as ratio is concerned, 0^{o} data and finite angle data are consistent with each other. Therefore reaction mechanism effect is negligible and we obtain the conclusion same as Ong, et. al..

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E314 198MeV & 295MeV & 392MeV: Phys. Lett. B 725, 277 (2013)
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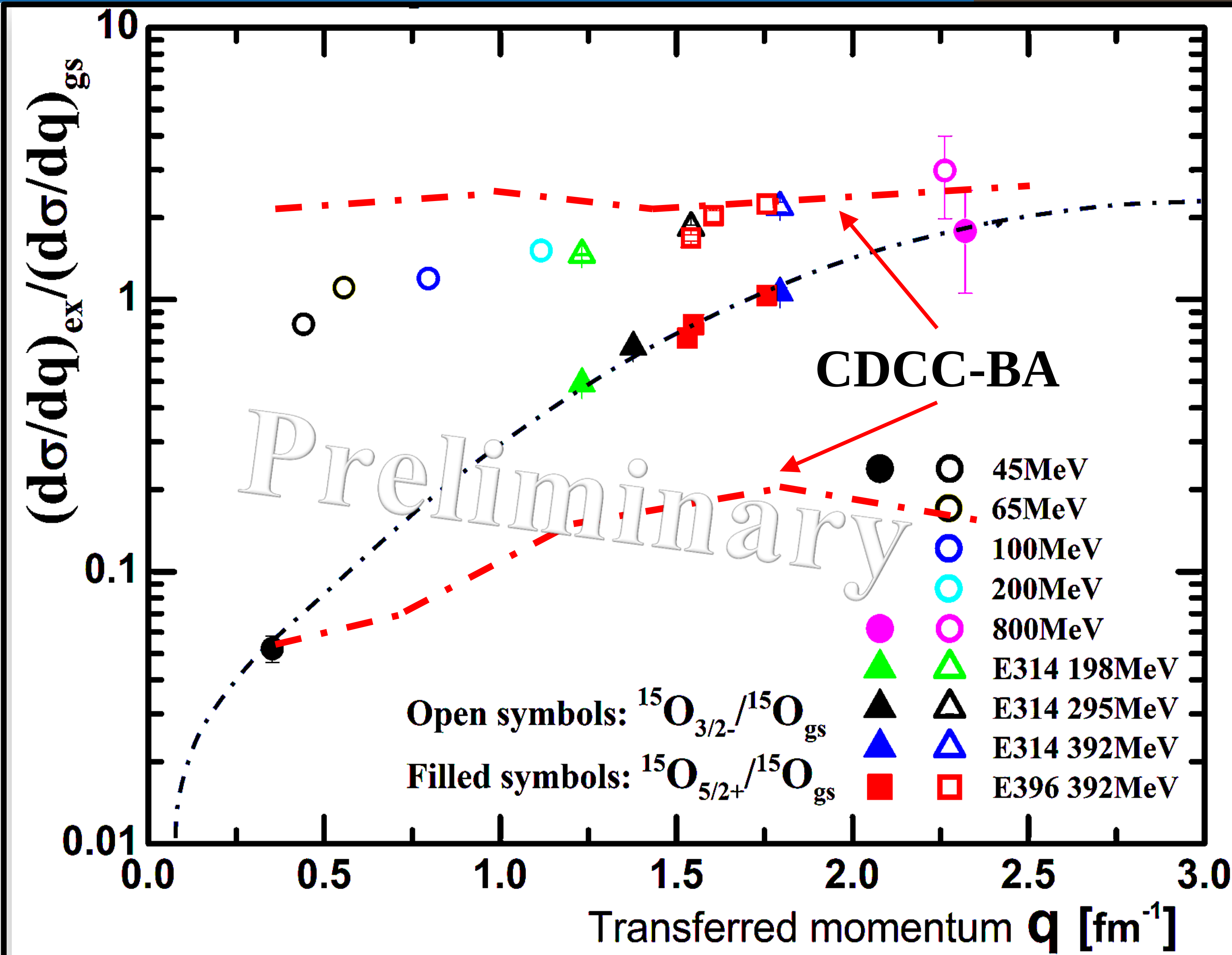


Among the ratio of cross sections of excited states (5/2+ & 3/2-) to ground state of ^{15}O, stronger momentum dependence is observed for the 5/2+ state, which is indicated to be consistent with the effect of tensor interactio

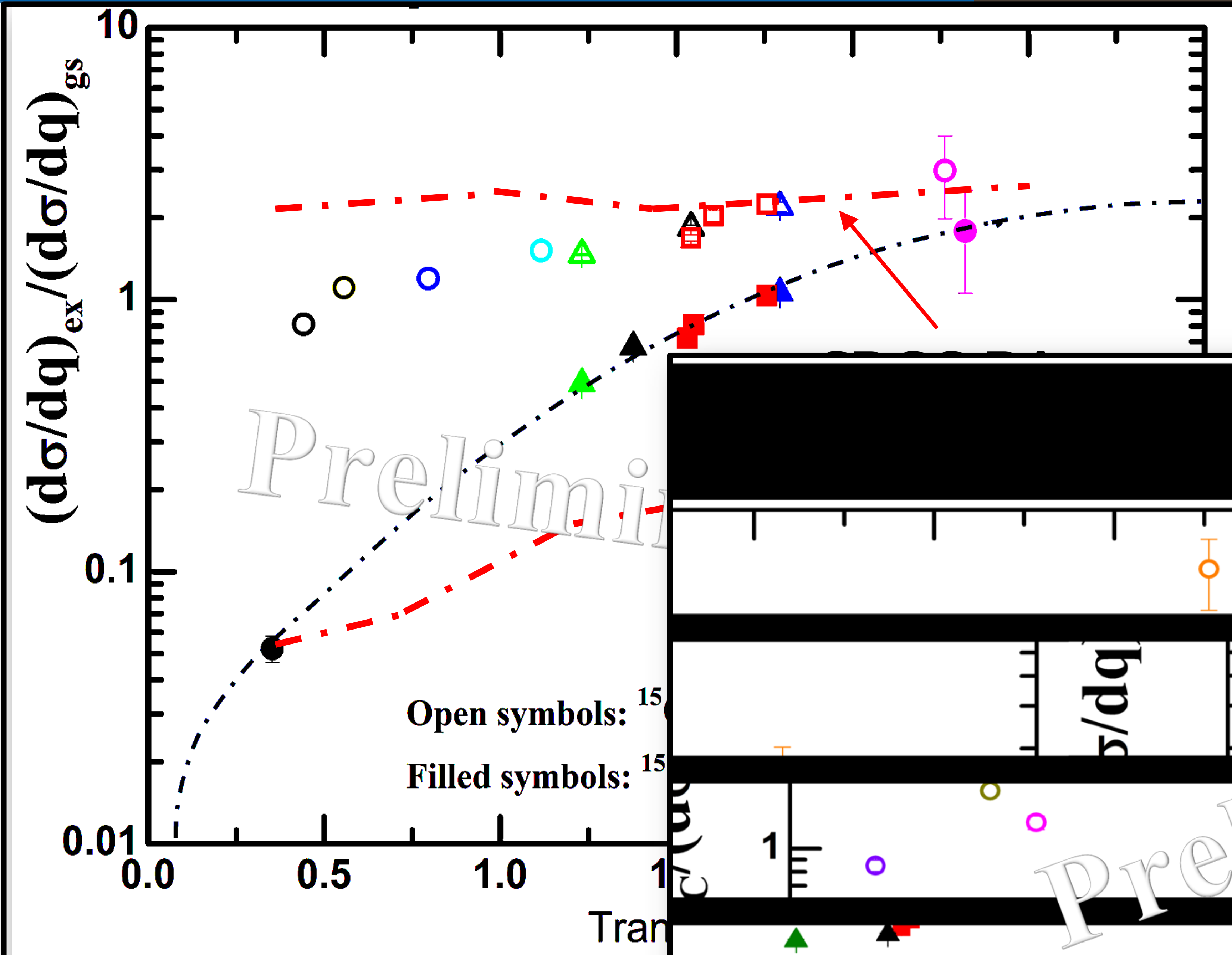
- **CDCC-BA calculation with known spectroscopic factors:**
  ✓ qualitatively agree with ratios for the neutron-hole states (3/2- to 1/2-)
  ✓ cannot explain the ratios for the positive-parity state (5/2+ to 1/2-)

- **Two(Multi)-step process does not help**

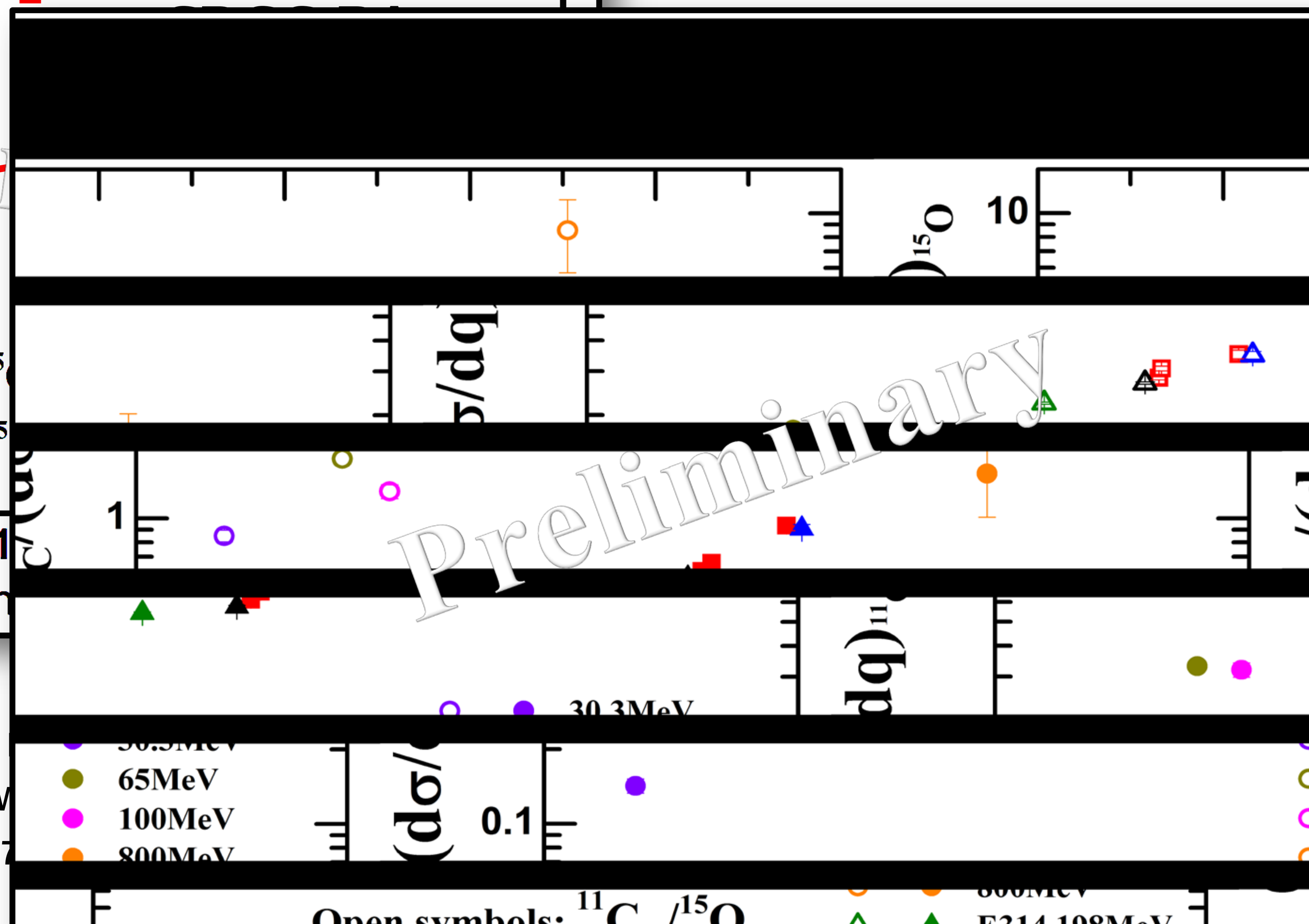
- **TOSCOM-type momentum wave functions** that include high-momentum components "fit" the data well.

T. Myo, PTP 117 (2007) 257.

45MeV: Phys. Rev. 187, 1246 (1969)　65MeV: Nucl. Phys. A 255, 187 (1975)
100MeV: Nucl. Phys. A 106, 357 (1968)　200MeV: Phys. Rev. C 39, 65 (1989)
E314 198MeV & 295MeV & 392MeV: Phys. Lett. B 725, 277 (2013)
800MeV: Phys. Rev. C 30, 593 (1984)



By comparing the ratio of cross sections of ground state (3/2-) and excited state (1/2-) of ^{11}C to ground state of ^{15}O, respectively, we observed a difference in the momentum transfer dependence in ^{11}C and ^{15}O ground state, which is also indicated to be consistent with the effect of tensor interaction.



30.3MeV: Nucl. Phys. A 99, 669 (1967) 65MeV:

100MeV: Nucl. Phys. A 106, 357 (1968) 800MeV

E314 198MeV & 295MeV & 392MeV: Phys. Lett. B 7

Summary

- Tensor force is the important part of nuclear force.
- Nucleon pick-up reaction is a good tool to probe the high-momentum component.
- We have studied the high-momentum neutrons in the initial gs-configuration by (p,d) reactions.
  - Among the ratio of cross sections of excited states (5/2+ & 3/2-) to ground state of ^{15}O, stronger momentum dependence is observed for the 5/2+ state, which is indicated to be consistent with the effect of tensor interaction.
  - As long as ratio is concerned, 0^{o} data and finite angle data are consistent with each other. Therefore reaction mechanism effect is negligible and we obtain the conclusion same as Ong, et. al..
  - By comparing the ratio of cross sections of ground state (3/2-) and excited state (1/2-) of ^{11}C to ground state of ^{15}O, respectively, we observed a difference in the momentum transfer dependence in ^{11}C and ^{15}O ground state, which is also indicated to be consistent with the effect of tensor interaction.

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WAVE FUNCTIONS

- The most important origin of the momentum distribution is the movement of nucleons in a nuclear potential and typically expressed by Fermi momentum (mainly momentum below 1 fm^{-1}).

- The momentum distributions are also affected by the n–n correlations. One of the well-known origins is the short-range repulsion of the central forces.

- The tensor forces also give a characteristic range in the n–n interaction and make a large contribution at momentum at around 2 fm^{-1}.