Search for a new type of giant resonance in nuclei : Giant Pairing Vibration

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CNS, the University of Tokyo

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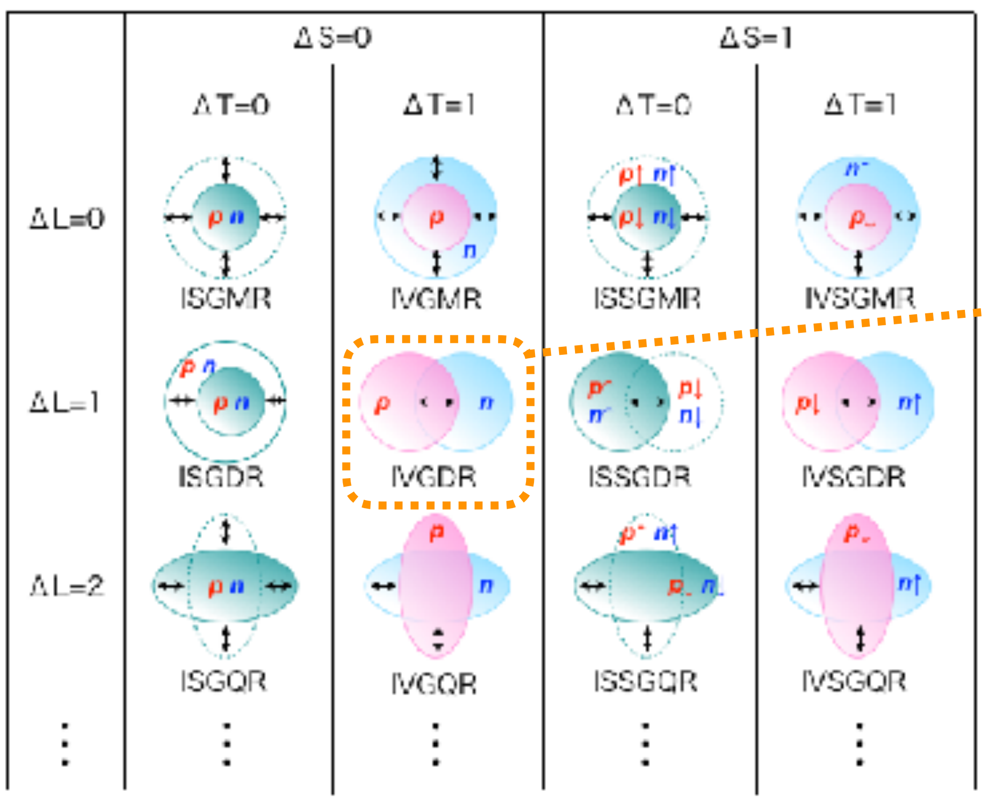
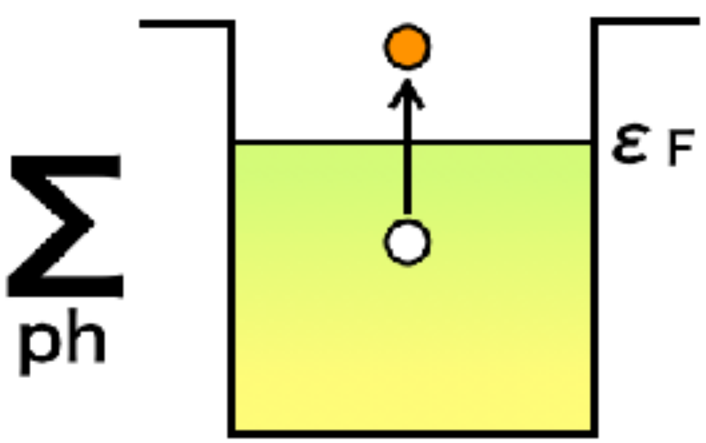
31 May — 1 June, 2019

Introduction

Giant Resonances (GR)

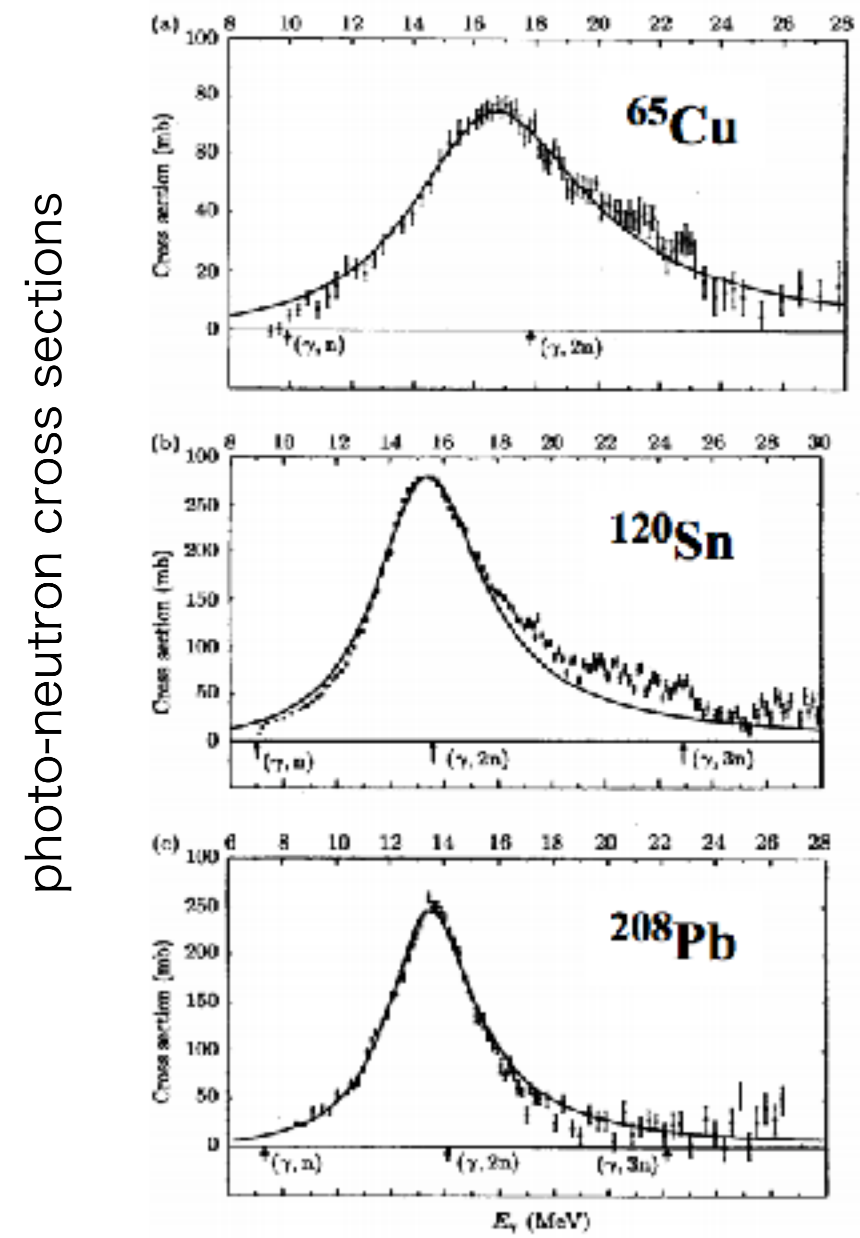
= Collective p-h excitations





Isovector giant dipole resonance

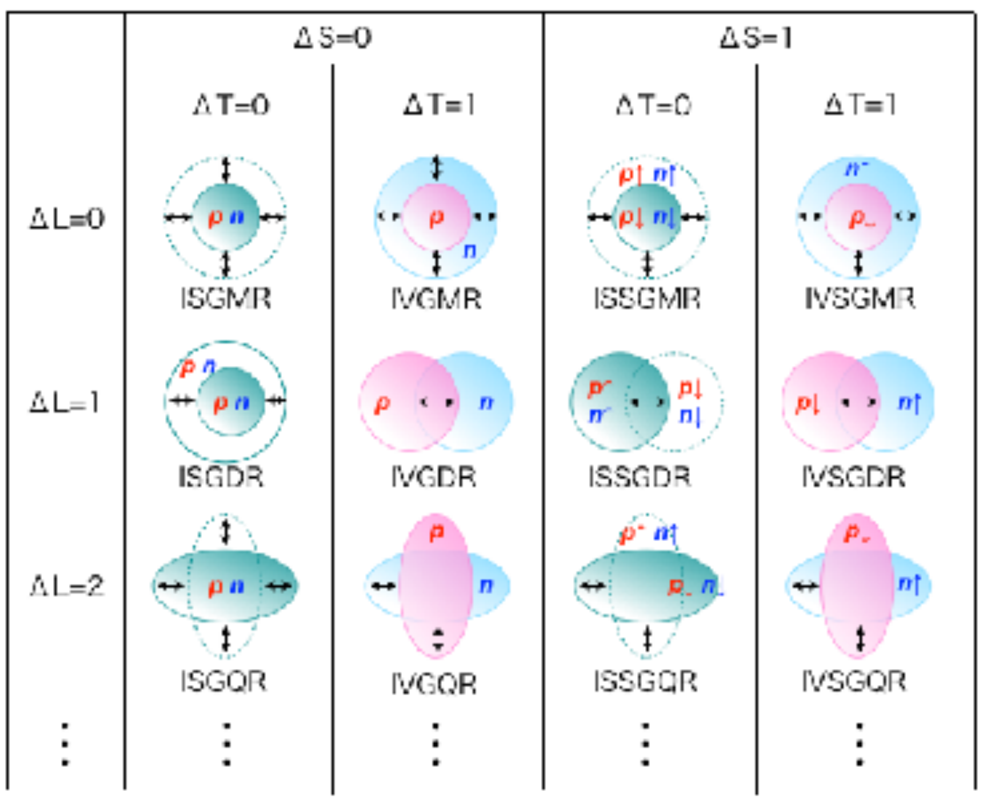
B.L.Berman and S.C.Fultz, Rev. Mod. Phys.47, 713 (1975).

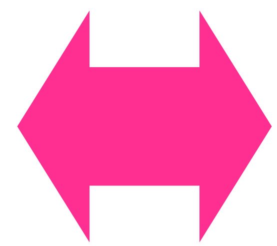


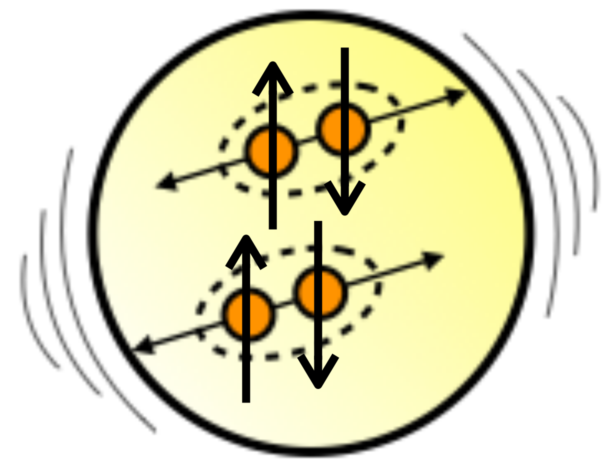
Introduction

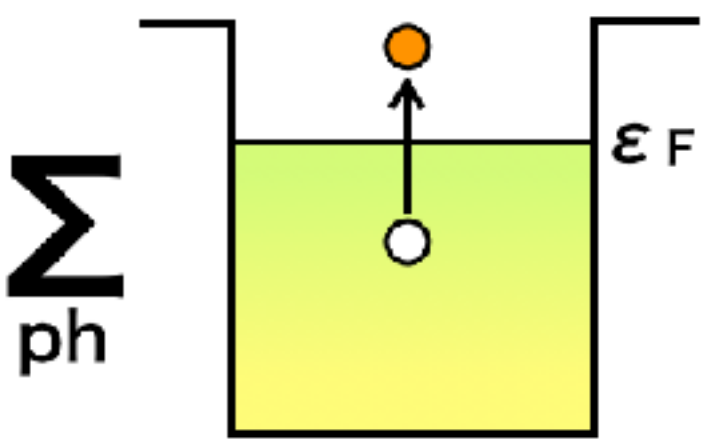
Giant Resonances (GR)
= Collective p-h excitations

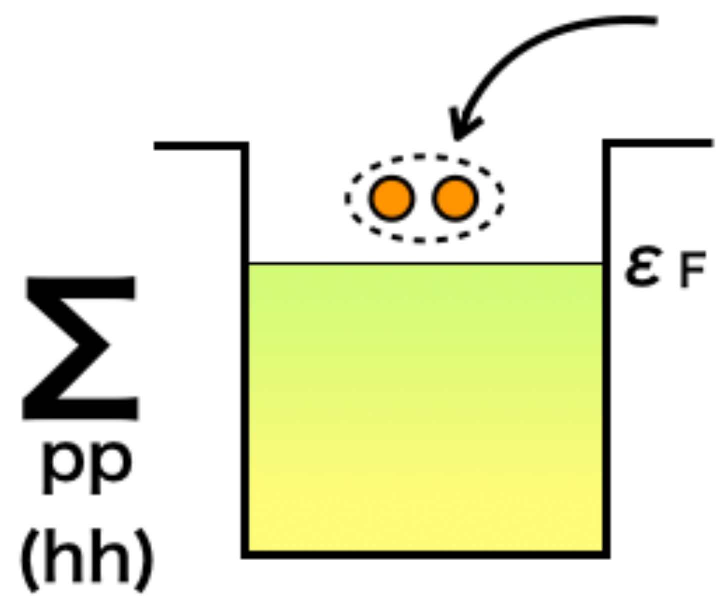
Giant Pairing Vibration (GPV)
= Collective p-p (h-h) excitations







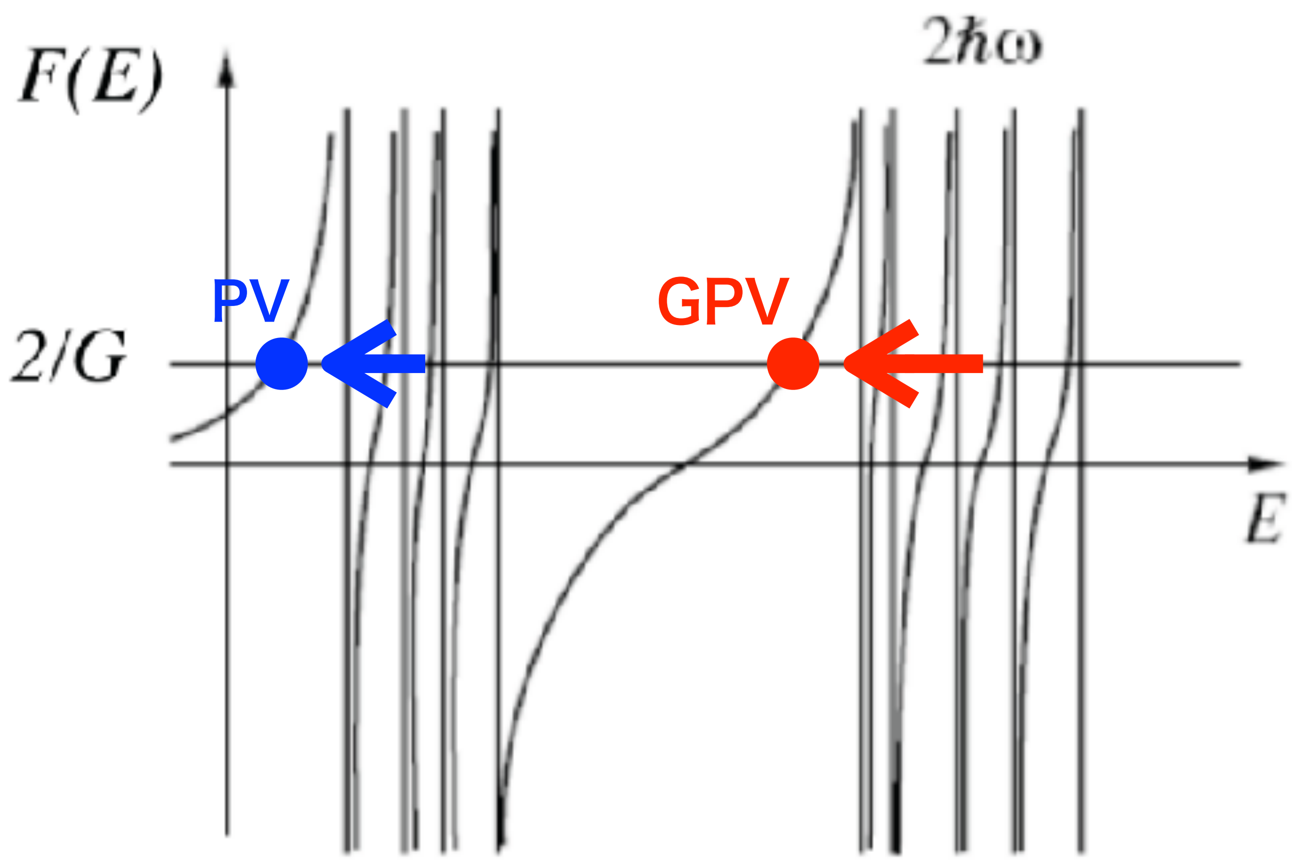




Giant Pairing Vibration (GPV)

R.A.Broglia and D.Bes, Phys. Lett. B 69, 129 (1977).
M.W.Herzog, R.J.Liotta, and T.Vertse, Pays. Lett. B 165, 35 (1985).

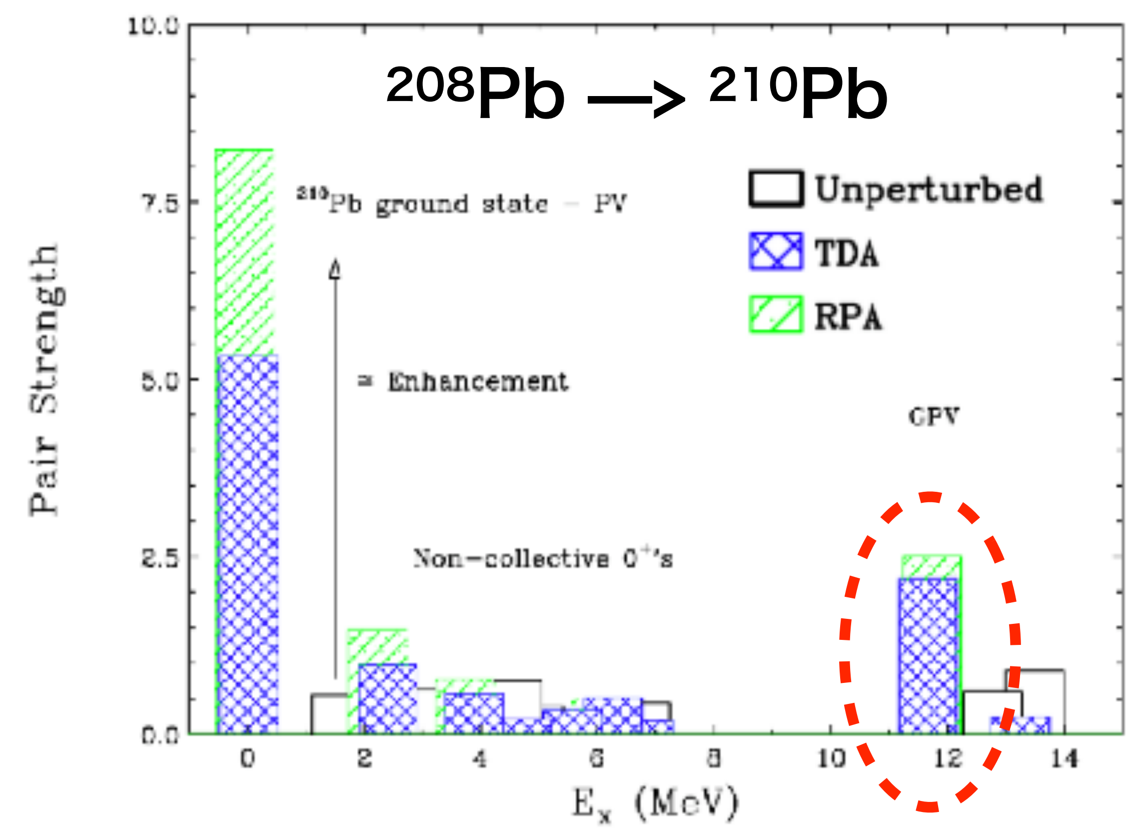
- Excitation of pair across major shells



$$H = \sum_j e_j (a_j^\dagger a_j + a_{\bar{j}}^\dagger a_{\bar{j}}) - G \sum_{j,k} a_j^\dagger a_{\bar{j}}^\dagger a_k a_{\bar{k}}$$

M.Laskin et al., Phys. Rev. C 93, 034321 (2016).

<u>Normal system</u>



M.Assie et al., arXiv:1905.01339

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R.A.Broglia and D.Bes, Phys. Lett. B 69, 129 (1977).
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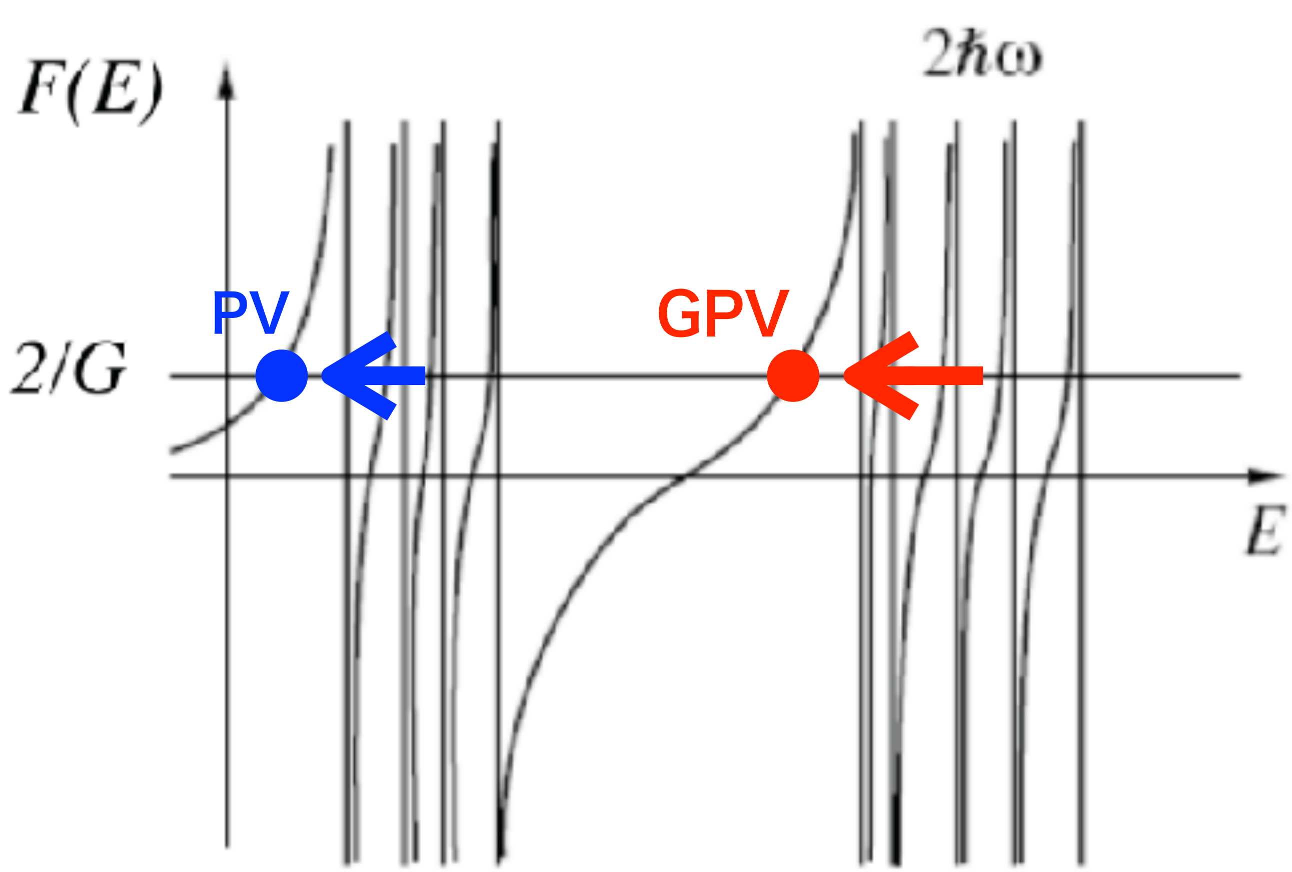

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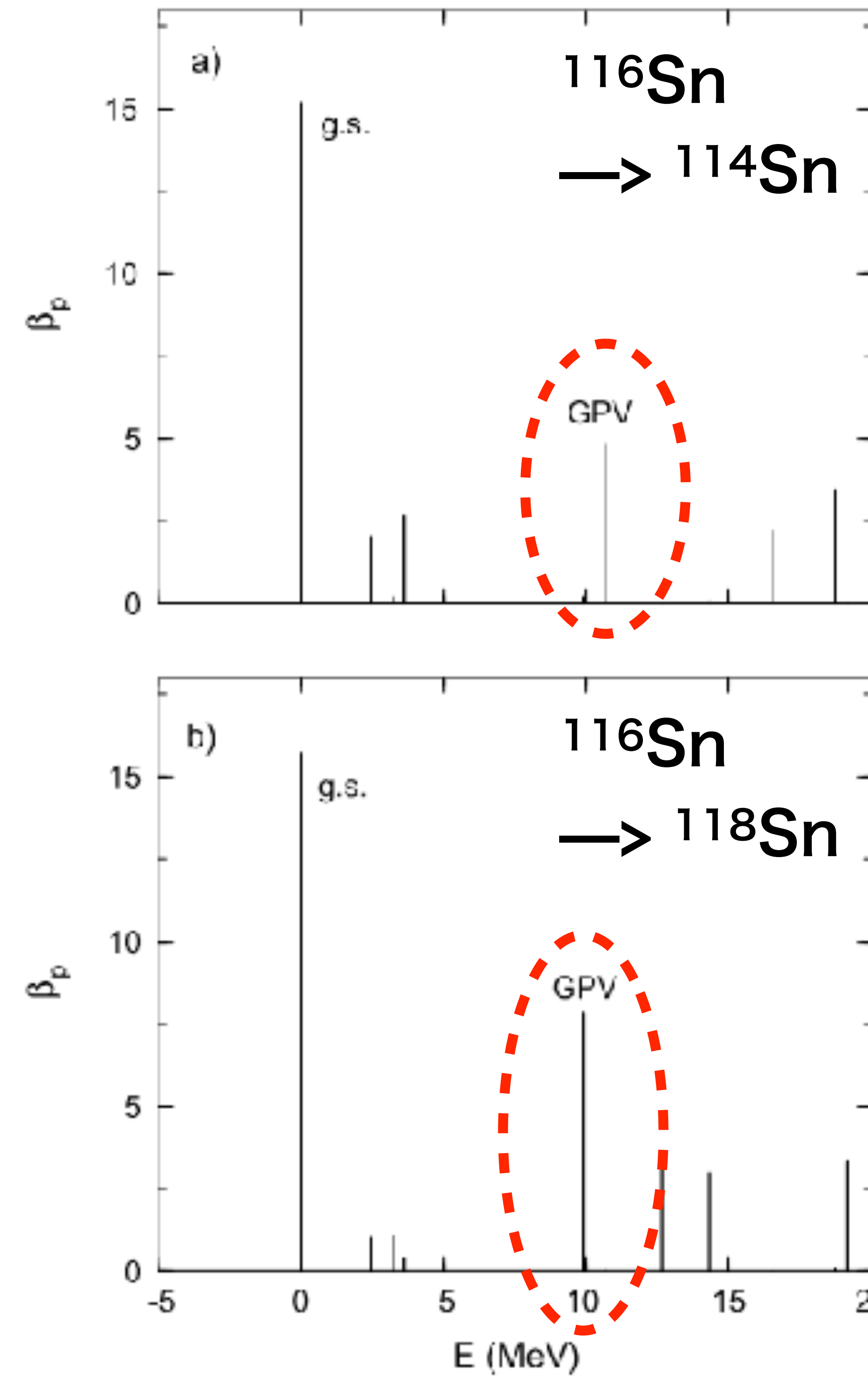
M.Laskin et al., Phys. Rev. C 93, 034321 (2016).

<u>Superfluid system</u>



L.Fortunato et al., Eur. Phys. J. A 14, 37 (2002).

Predicted properties of GPV

- L=0 multipolarity ($J^{\pi}=0^{+}$)
- Excitation Energy ~ 65 $A^{-1/3}$
  (~ 12 — 20 MeV)
- FWHM ~ 1-2 MeV
- Collectivity : B(GPV) ~ B(PV)
- Universality

R.A.Broglia and D.Bes, Phys. Lett. B 69, 129 (1977).
M.W.Herzog, R.J.Liotta, and T.Vertse, Pays. Lett. B 165, 35 (1985).

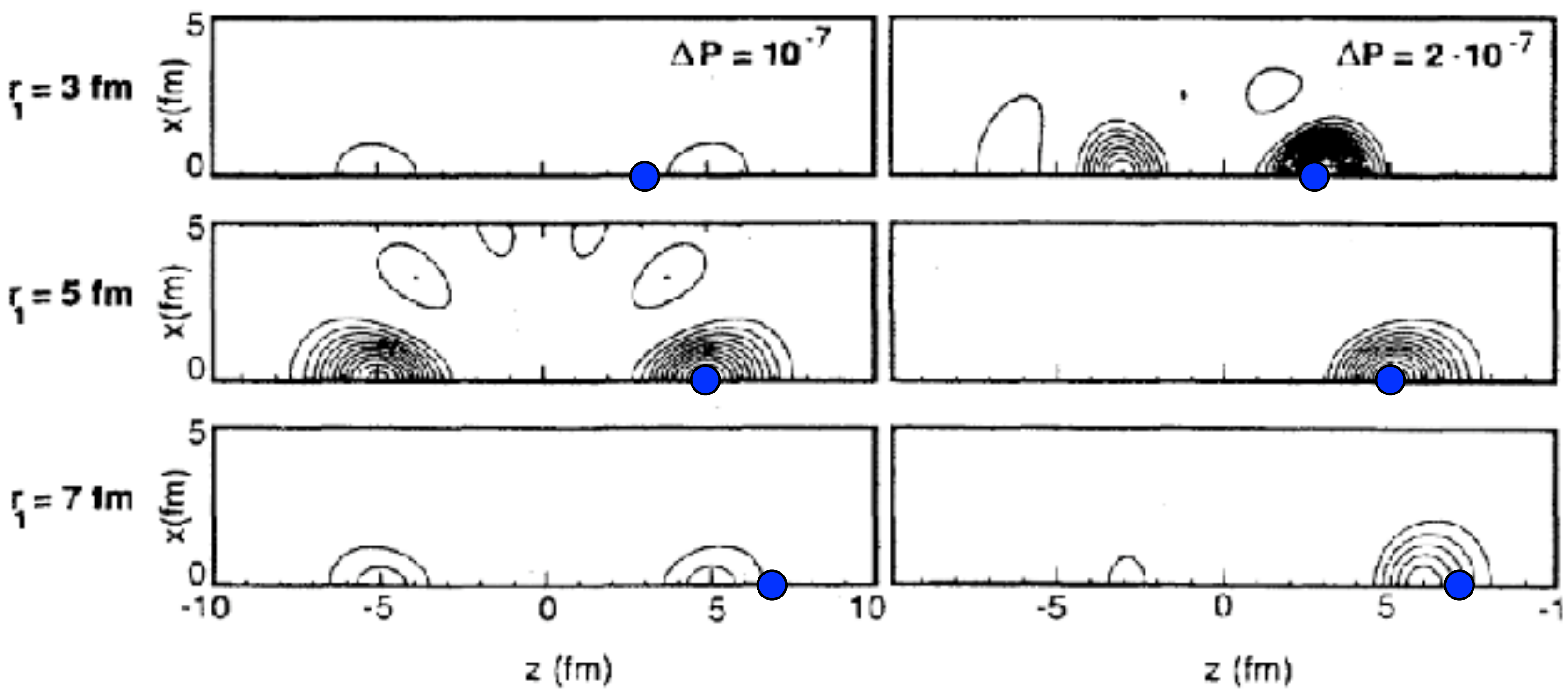
Predicted properties of GPV

$|\Psi(r_1,r_2)|^2$ as a function of r_2, for fixed r_1

Pure conf. $(0h_{9/2})^2$

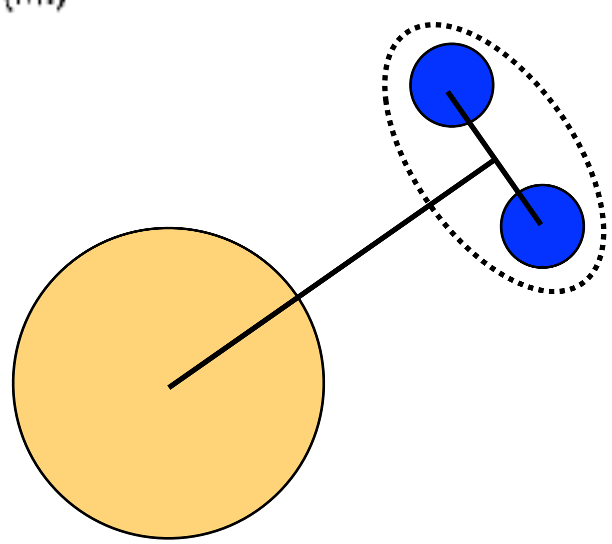
Correlated

F. Catara et al., Phys. Rev. C 29, 1091 (1984).
P.Lotti et al., Phys. Rev. C 40, 1791 (1989).



$^{120}Sn(GPV)$
$= {}^{118}Sn(g.s.) \otimes 2n$

● position of particle 1



Spatial (dineutron-like) correlations

Experimental attempts

- **Many studies using (p,t) reactions**

G.M.Crawley et al., Phys. Rev. Lett. 39, 1451 (1977).
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G.M.Grawley et al., Phys. Rev. C 23, 589 (1981).
B.Mouginot et al., Phys. Rev. C 83, 037302 (2011).
M.De.Napoli et al., Acta Phys. Pol. B 4, 437 (2014).

NEVER EXPERIMENTALLY OBSERVED

~1980's

Sn(p,t) @ 42 MeV

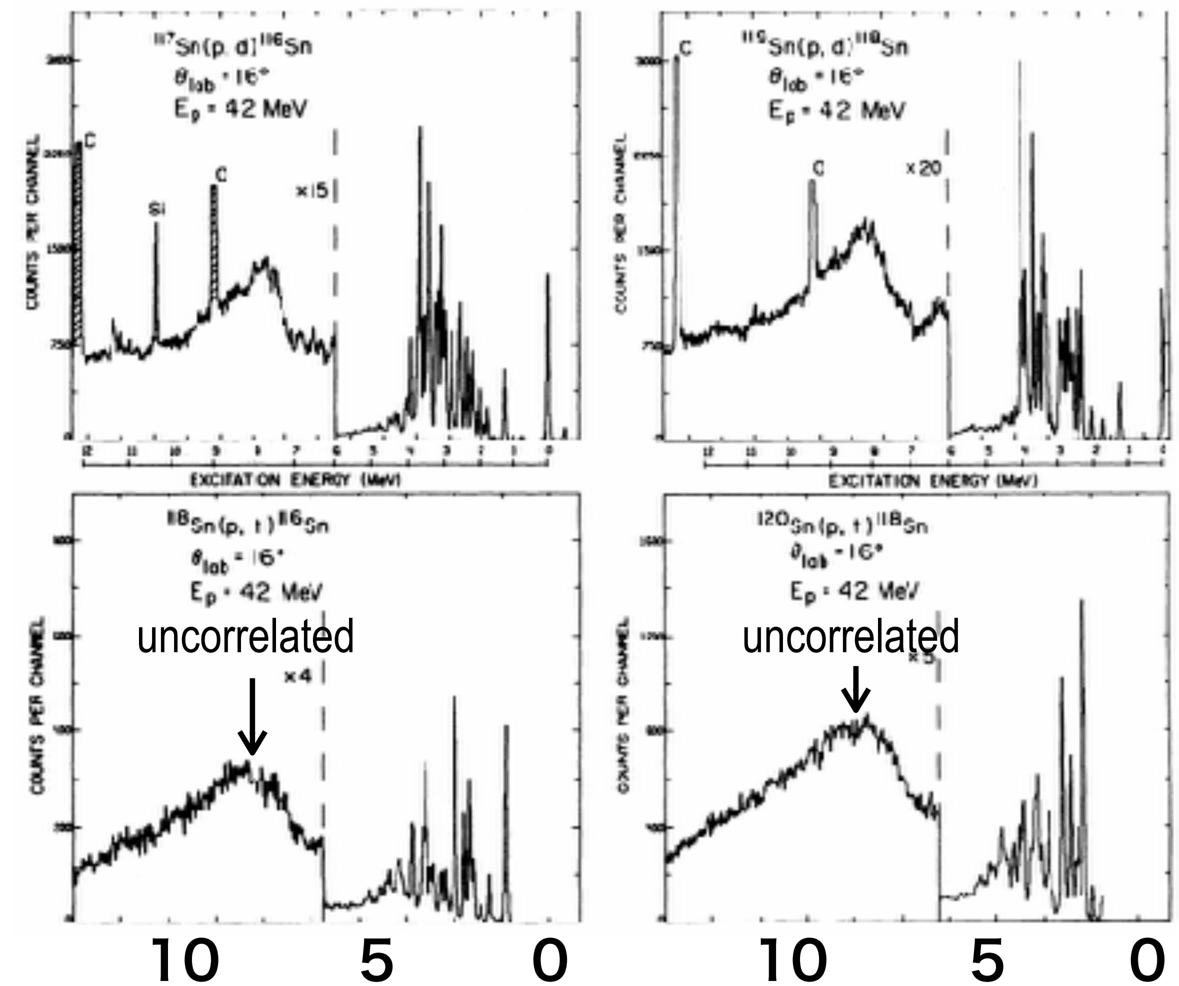
G.M.Grawley et al., Phys. Rev. C 23, 589 (1981).

No evidence

^{116}Sn ^{118}Sn

(p,d)

(p,t)



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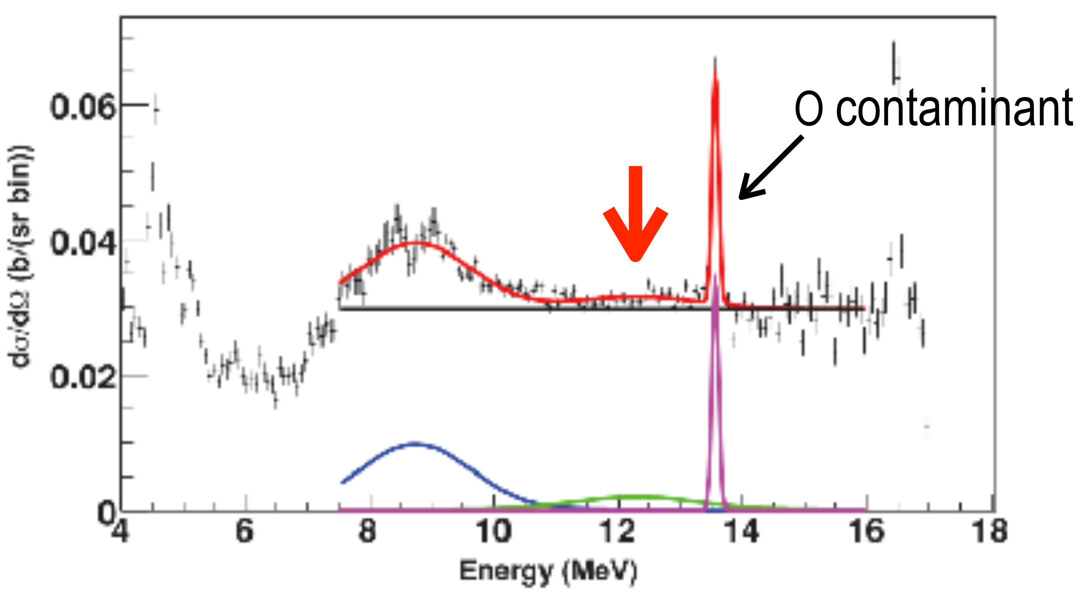
B.Mouginot et al., Phys. Rev. C 83, 037302 (2011).
M.De.Napoli et al., Acta Phys. Pol. B 4, 437 (2014).

NEVER EXPERIMENTALLY OBSERVED

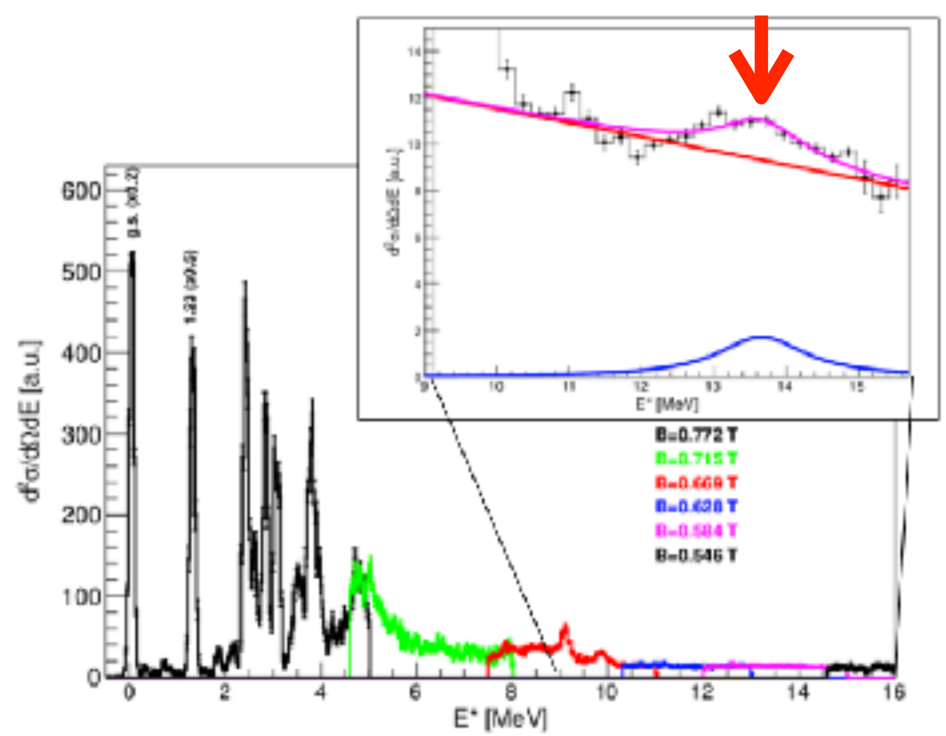
2000's

^{120}Sn(p,t) @ 50 MeV & 0^o



B.Mouginot et al., Phys. Rev. C 83, 037302 (2011).

^{120}Sn(p,t) @ 35 MeV & 8^o — 12^o



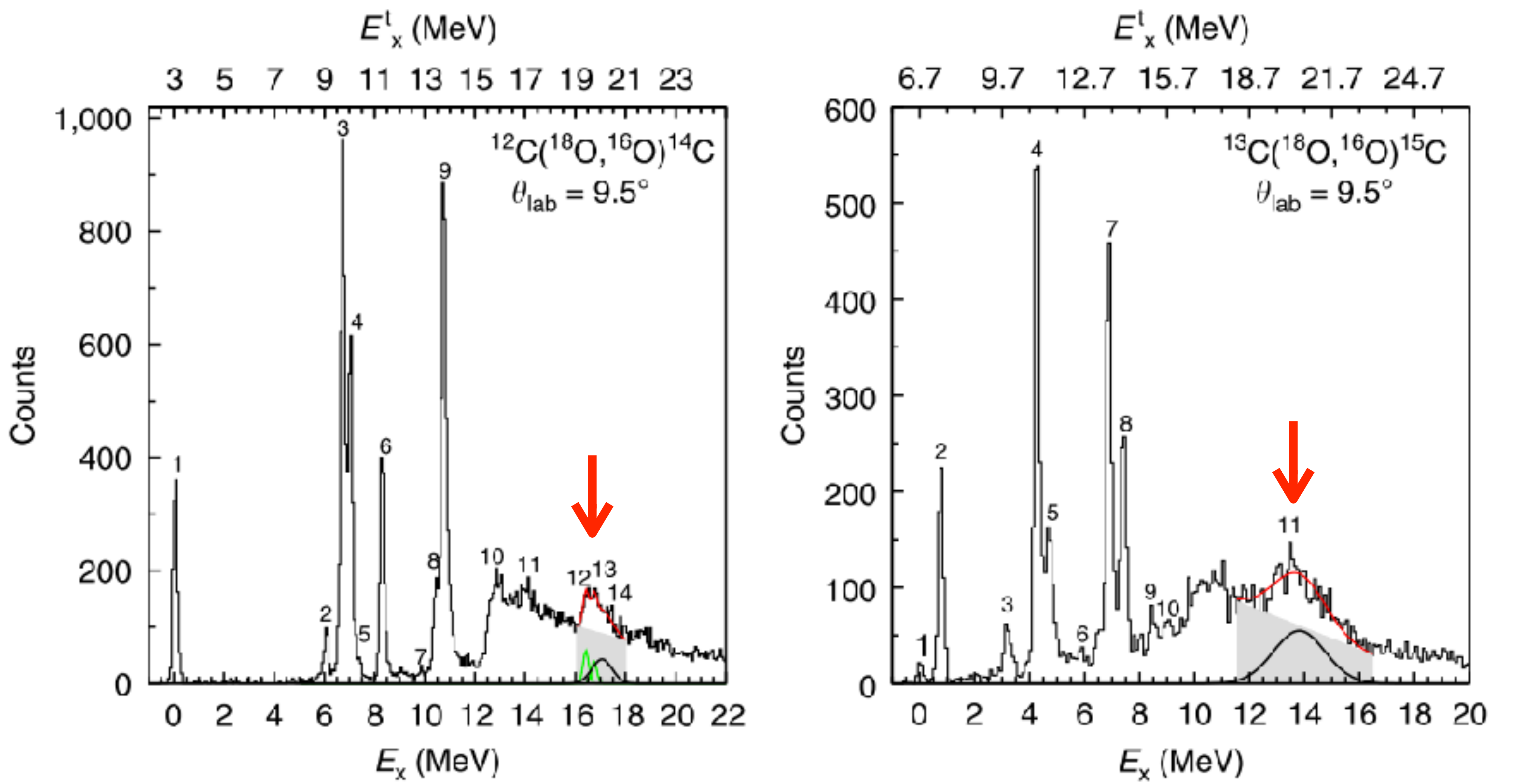
M.De.Napoli et al., Acta Phys. Pol. B 4, 437 (2014).

Small structure at ~12 MeV ?

Recent experiments with (^{18}O,^{16}O)

$^{12,13}C(^{18}O,^{16}O)^{14,15}C$ at 84 MeV

F.Cappuzzello et al., Nat. Commun. 6, 6743 (2015).



First signature of GPV, but in LIGHT nuclei

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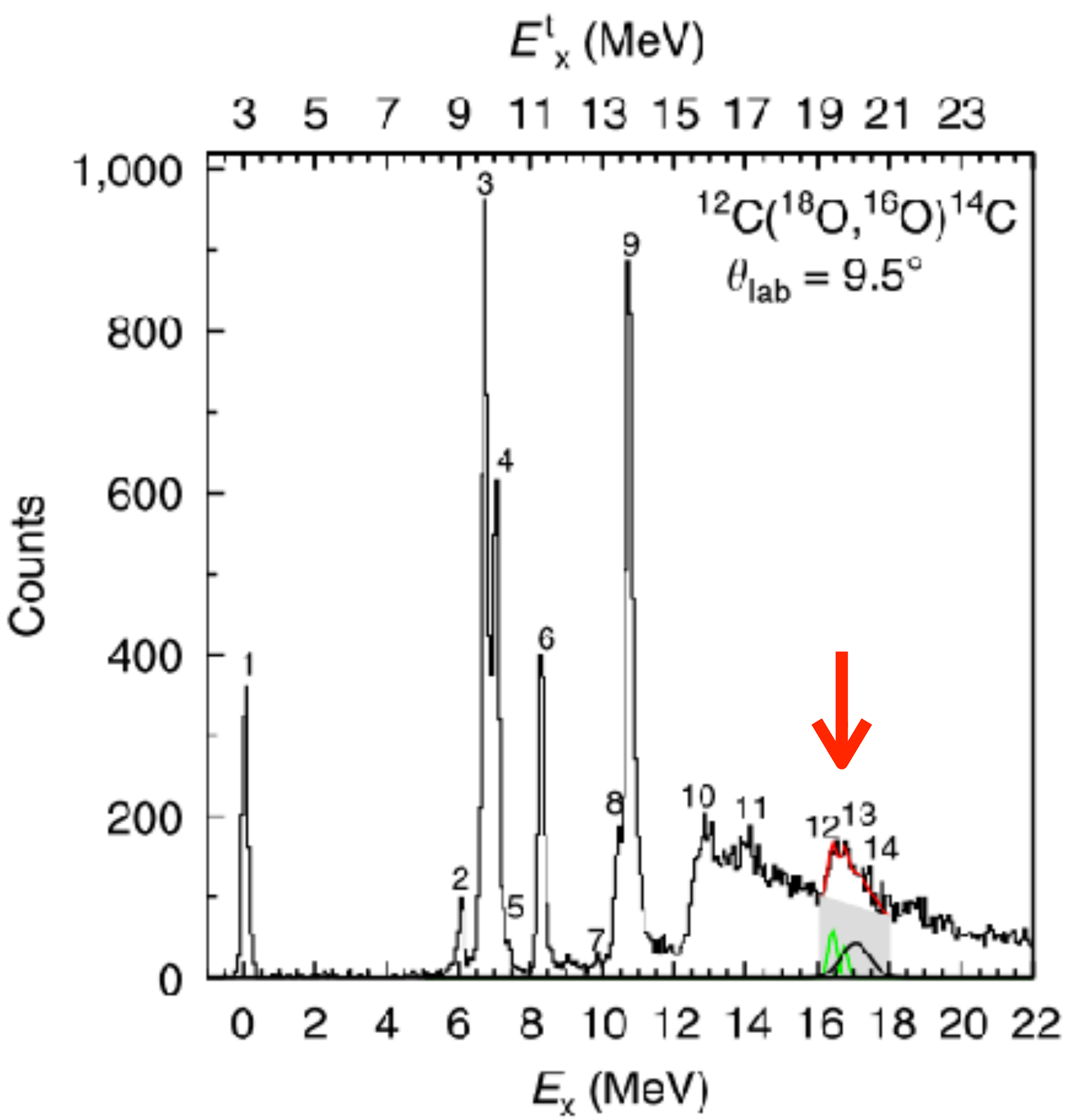
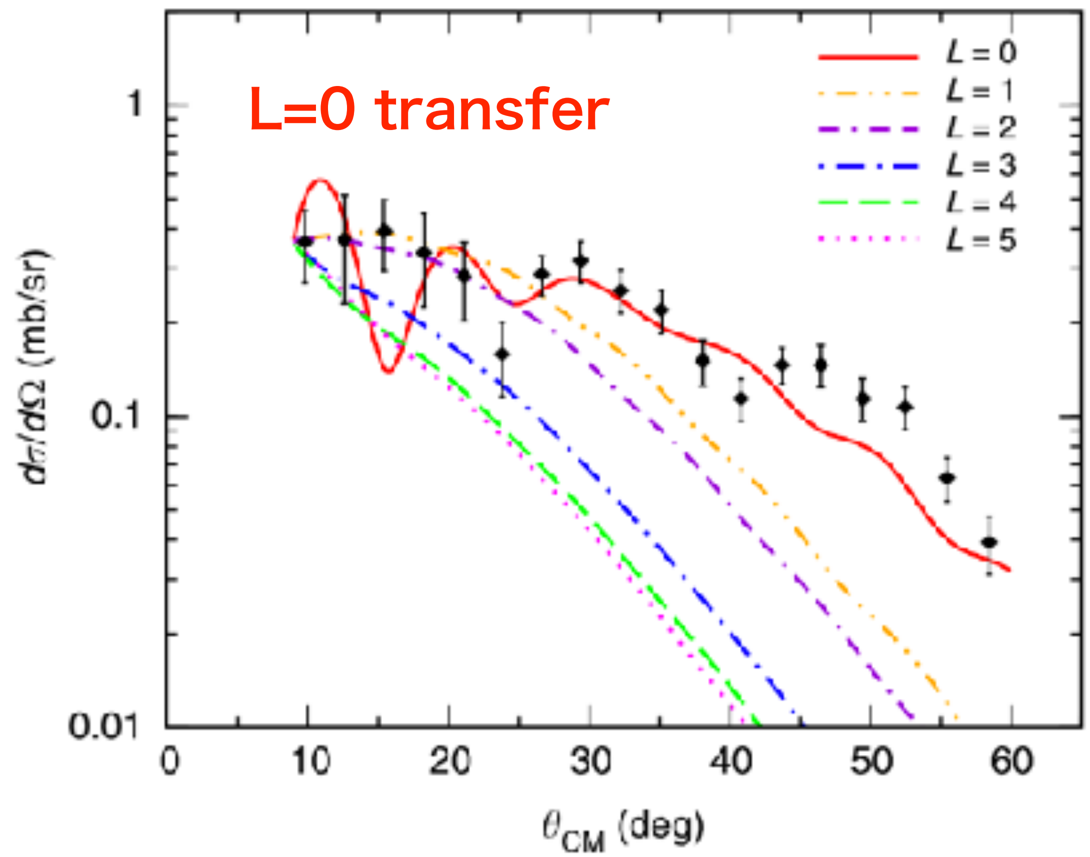


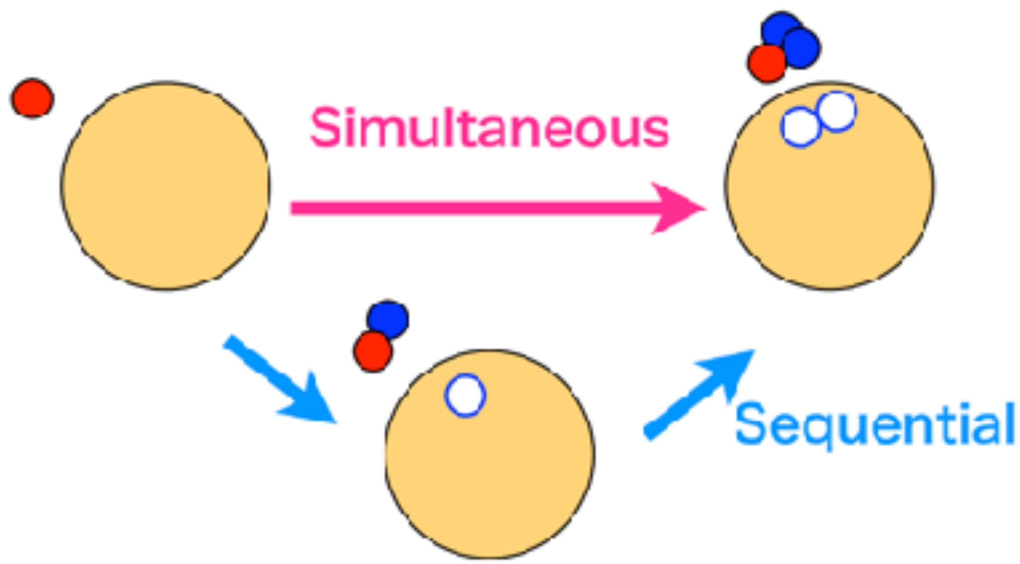


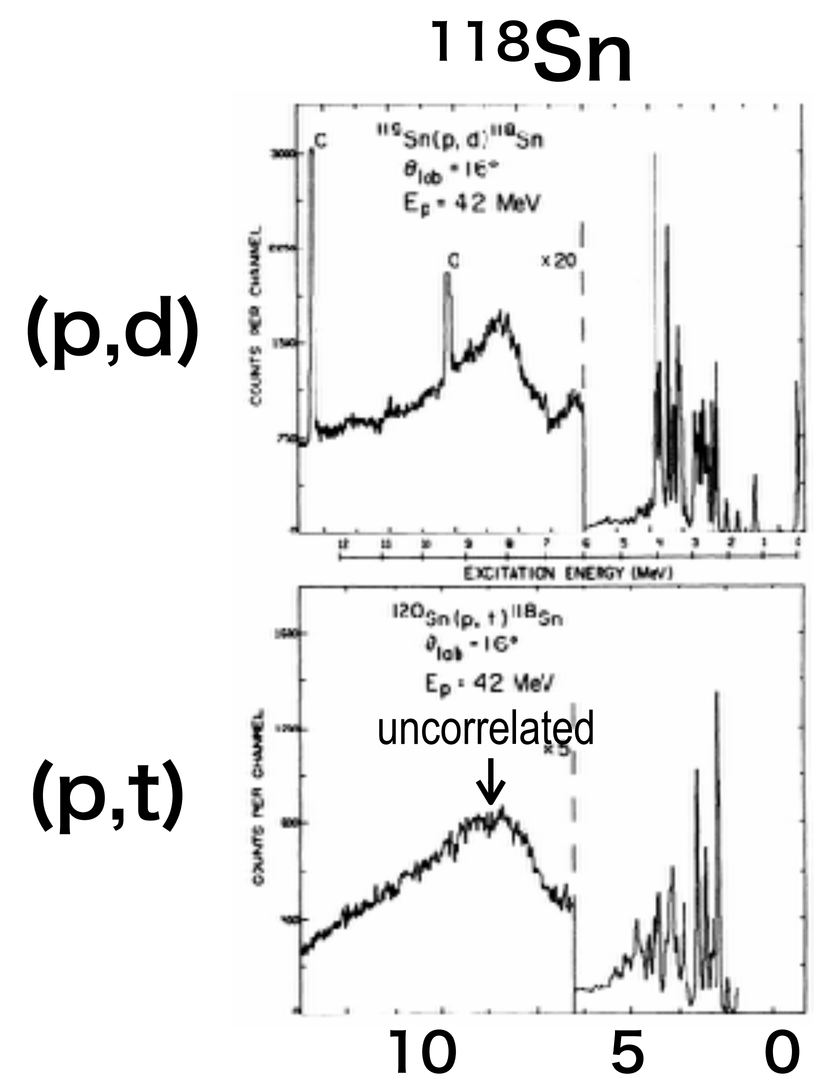
First signature of GPV, but in LIGHT nuclei

Question

Why has GPV not been observed in heavy nuclei ?

- Fragmentation ?
- Signal of GPV is masked by other states (uncorrelated states etc.) ?





	Correlated states	Uncorrelated states
Simultaneous	○	×
Sequential	○	○

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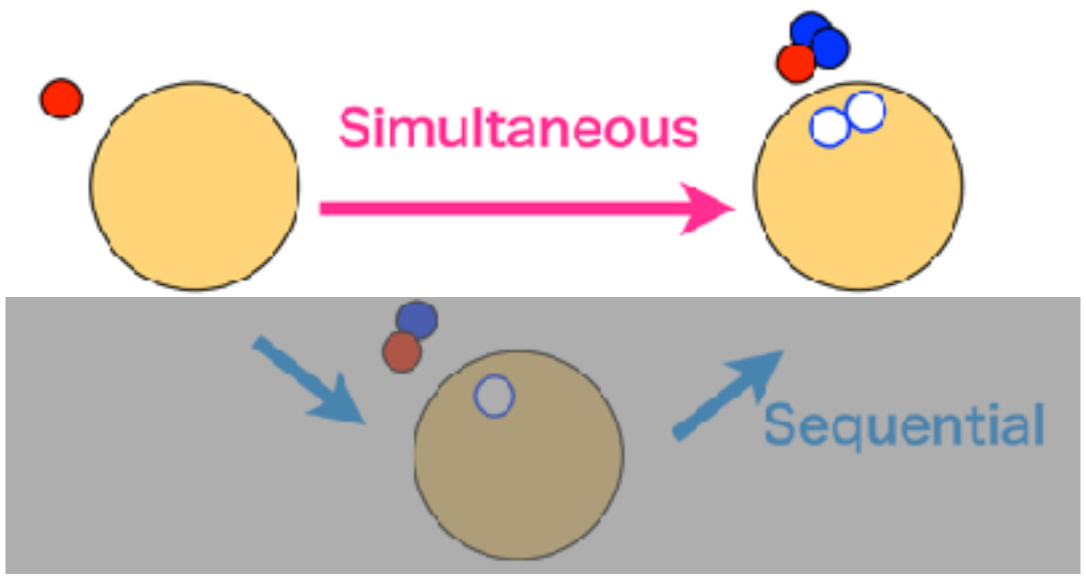
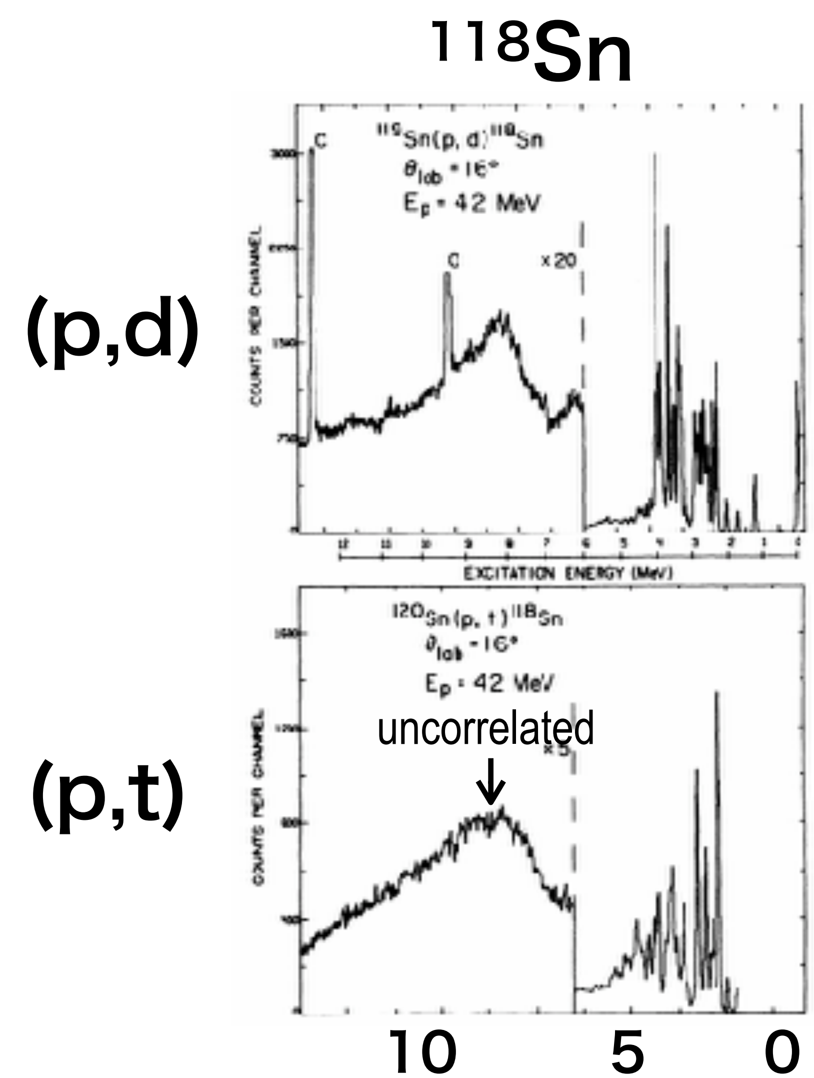
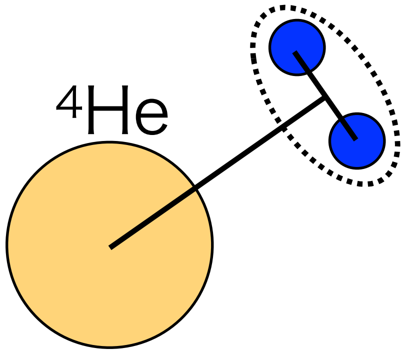




	Correlated states	Uncorrelated states
Simultaneous	○	×
Sequential	○	○

^{6}He : a breakthrough ?

- **Unique features**
  - two-neutron halo, Borromean, dineutron



Large dominance of 2n over 1n transfer cross sections

Yu.Ts.Oganessian et al., Phys. Rev. C 60, 044605 (2000).

A.Chatterjee et al., Phys. Rev. Lett. 101, 032701 (2008).

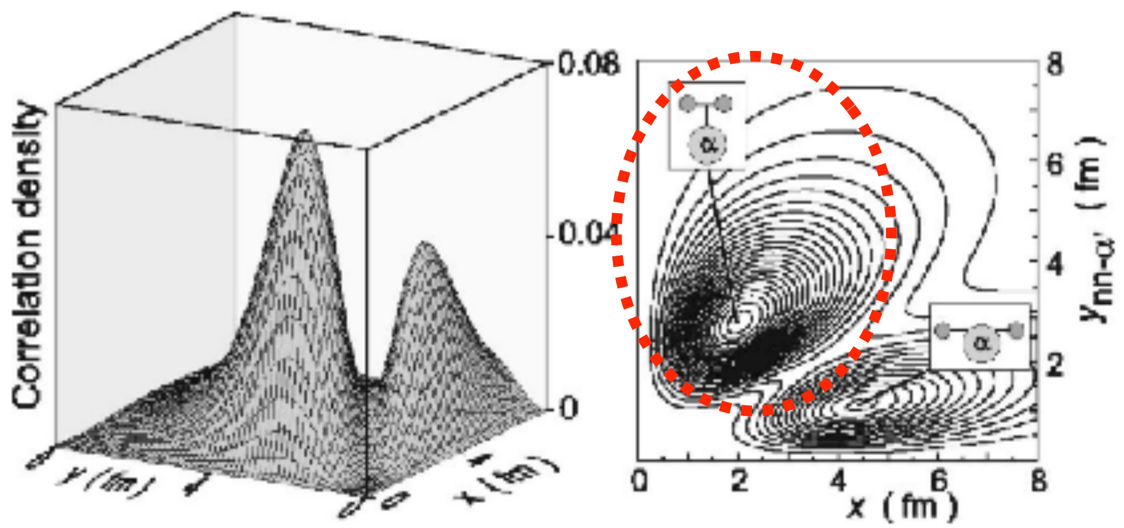
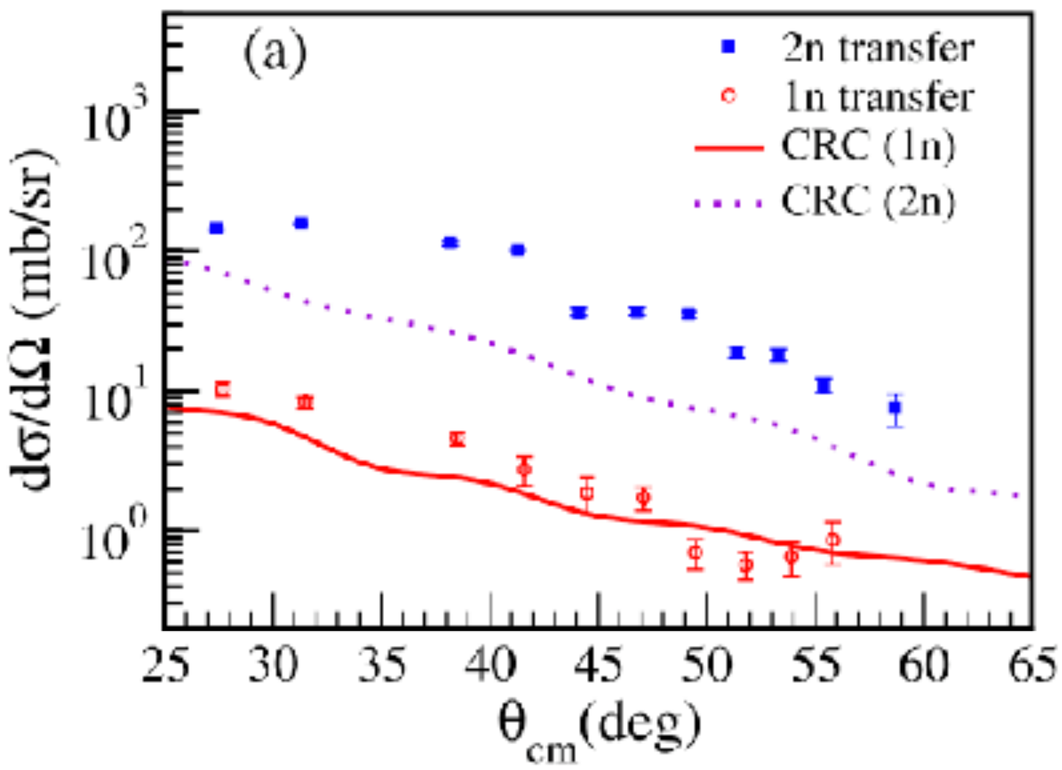


FIG. 3. Spatial correlation density plot for the ground state of ^{6}He. x is the distance between two valence neutrons and y is the distance from the α core to the (nn) center of mass. Dineutron and cigarlike components are clearly present.

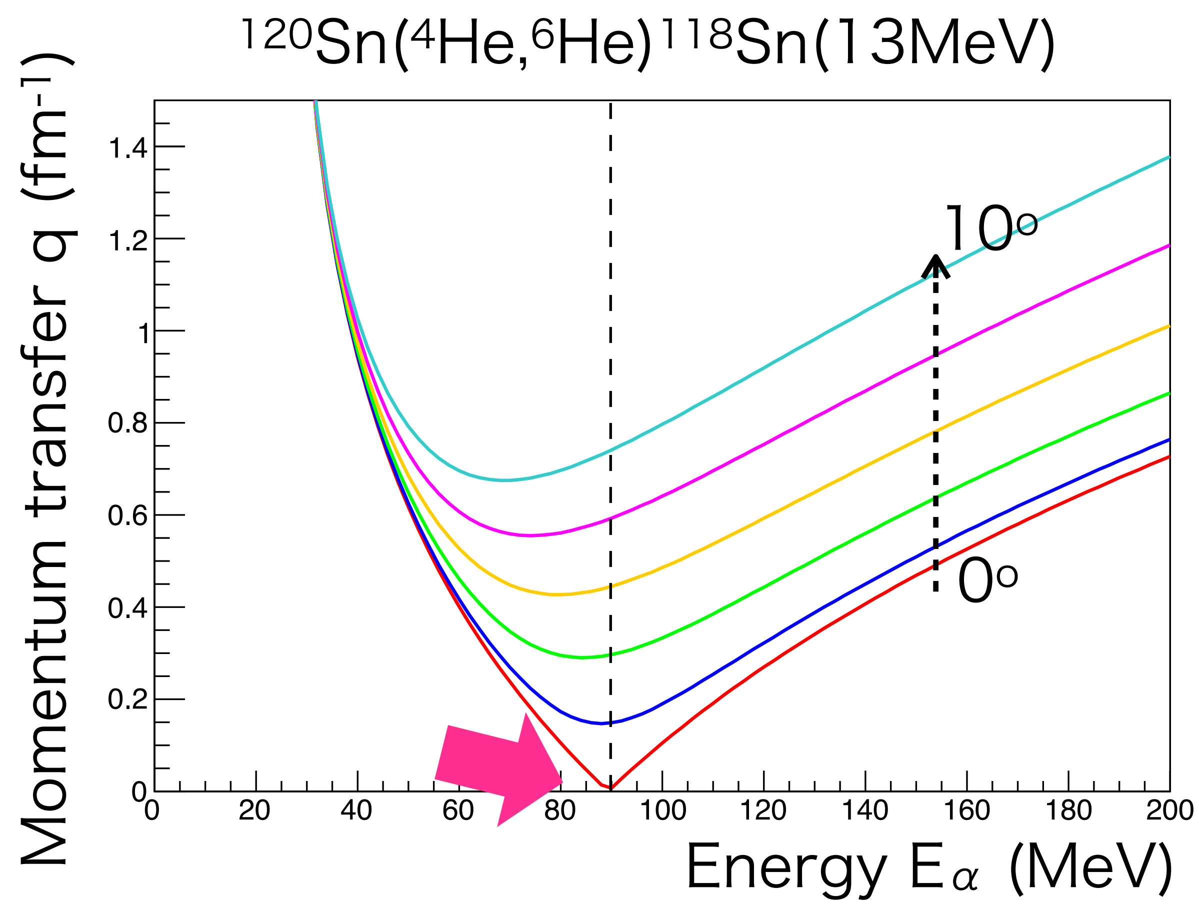
^{6}He + ^{65}Cu at 22.6 MeV



^{6}He has a potential to study correlated neutron pair states selectively

(^{4}He,^{6}He) reaction

- **(^{4}He,^{6}He) has some advantages, compared with (^{6}He,^{4}He)**
  - **Recoilless condition (q = 0 fm^{-1})** can be achieved
    —> Enhance L=0 transfer

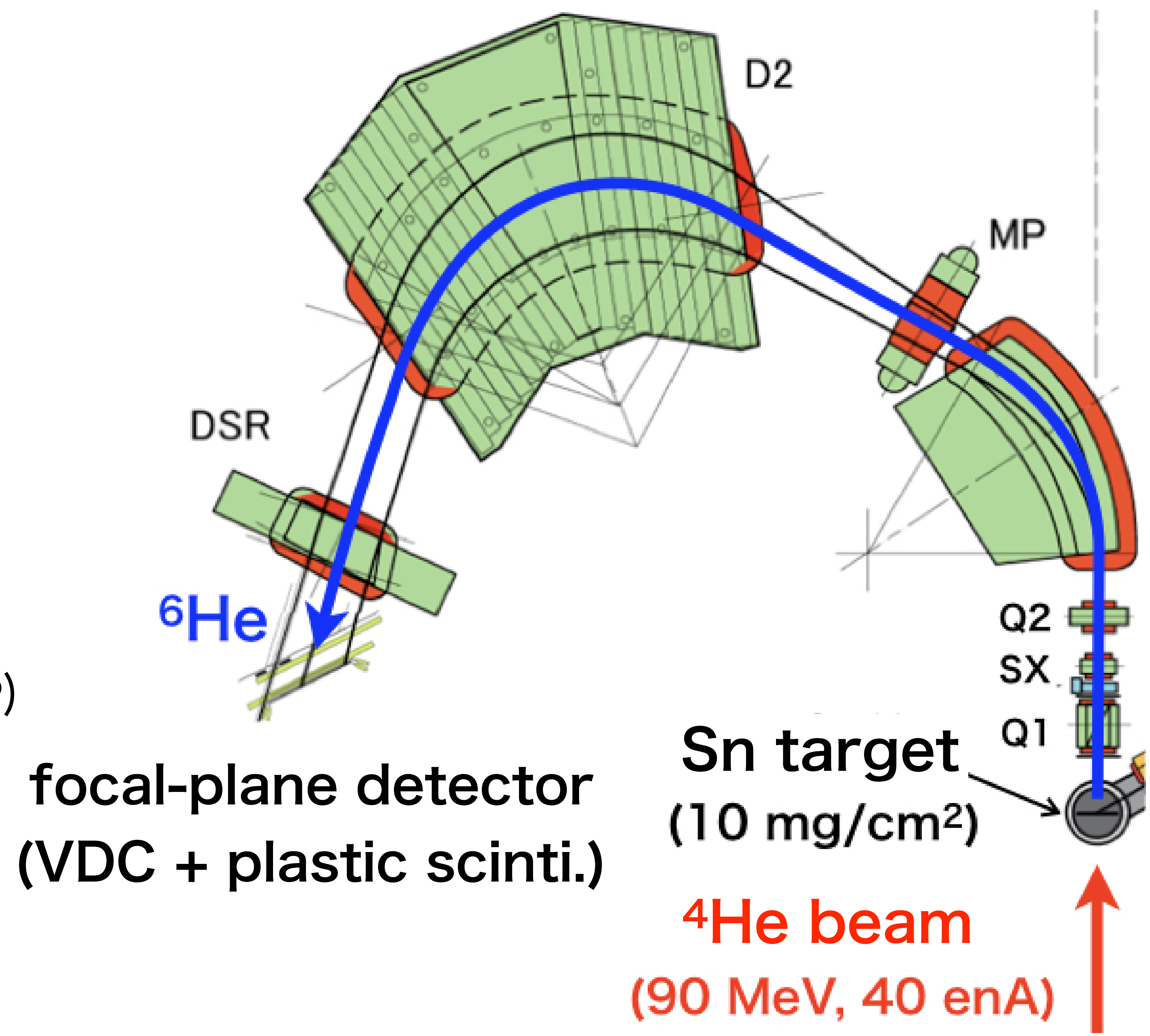


  - **No B.G. from 2n breakup (^{6}He —> ^{4}He + 2n)**
  - **High-intensity primary beam** (^{4}He) can be used
    —> High quality data (statistics, resolution, . . .)

GPV studies with (^{4}He,^{6}He) reaction

- **Facility : RCNP, Osaka University**
- **Beam : ^{4}He**
  - 90 MeV (recoilless)
  - 40 enA
- **Target : Sn isotopes**
  - A = 116 — 124
  - 10 mg/cm^2
- **^{6}He detection**
  - Grand Raiden ($\theta = 1^\circ$ — 6°)
  - LAS ($\theta = 6$ — 20°)
  - q ~ 0.1 — 1.5 fm^{-1}

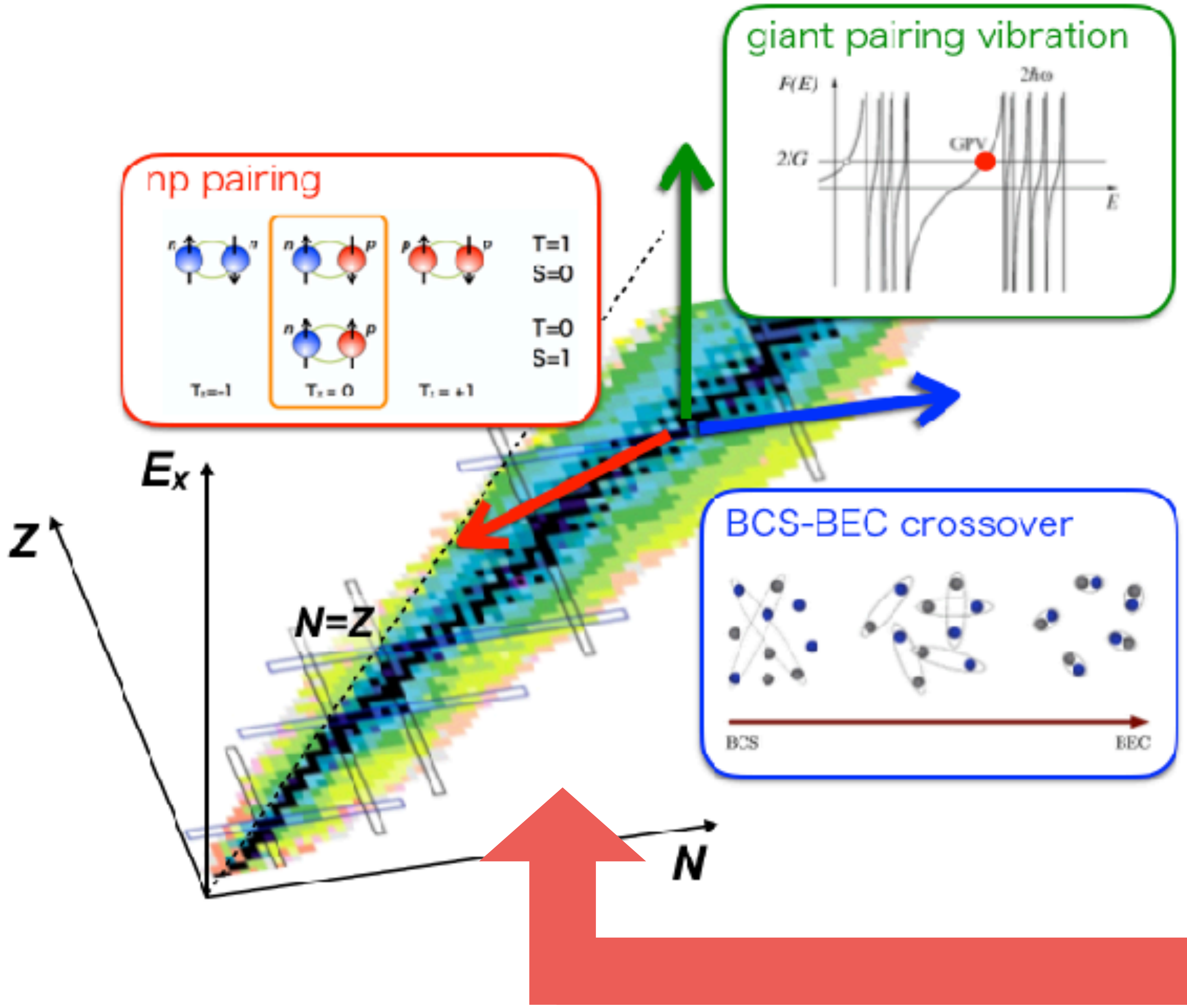
Grand Raiden or LAS



Summary

- **We would like to confirm existence of GPV in Sn isotopes**
- **(^4He,^6He) may be a good probe to populate GPV selectively**
- **Sn(^4He,^6He) experiment @ RCNP**
- **Plan (in two years)**
  - Development of reaction theory
    - Theoretical support : Ichimura-san (RIKEN)
  - Test experiment @ CYRIC ?
    - Difference between (p,t) & (^4He,^6He)

“Playground” for pairing studies



S.Michimasa et al.,
Prog. Theor. Exp. Phys. 2019, 043D01 (2019).

constructed at RIBF (2017~)

OEDO provides a good opportunity
to study exotic phenomena
induced by pairing correlations !!

OEDO : New beam line for
high-quality slow-down RI beams