

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

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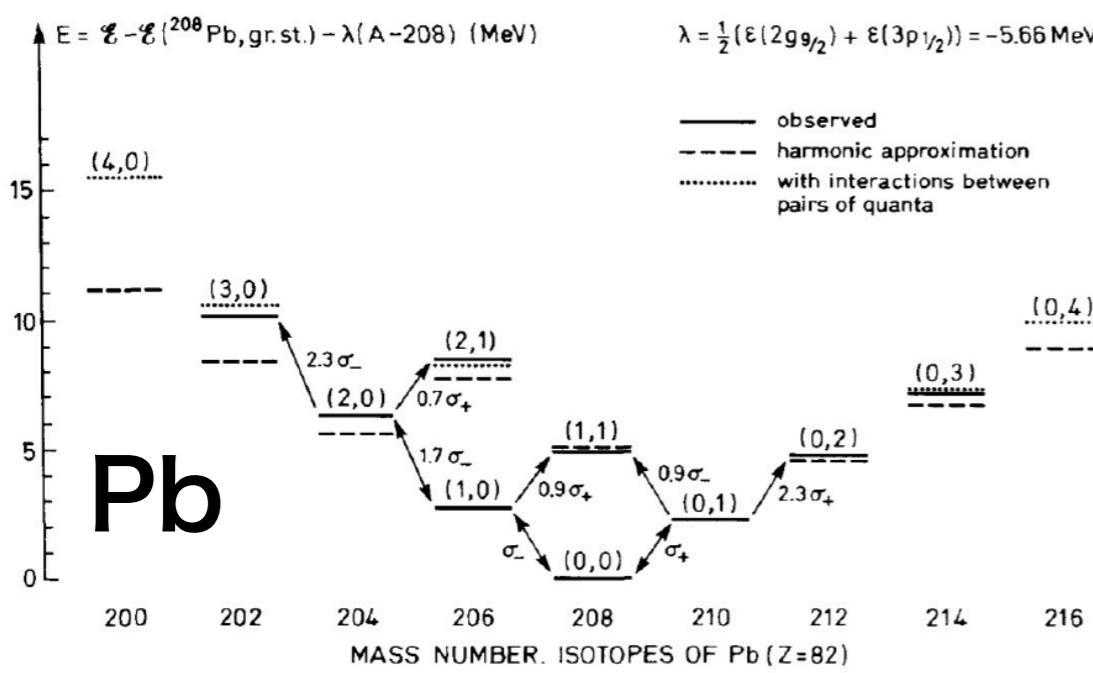
# Pairing force

- Affects the structure of atomic nuclei

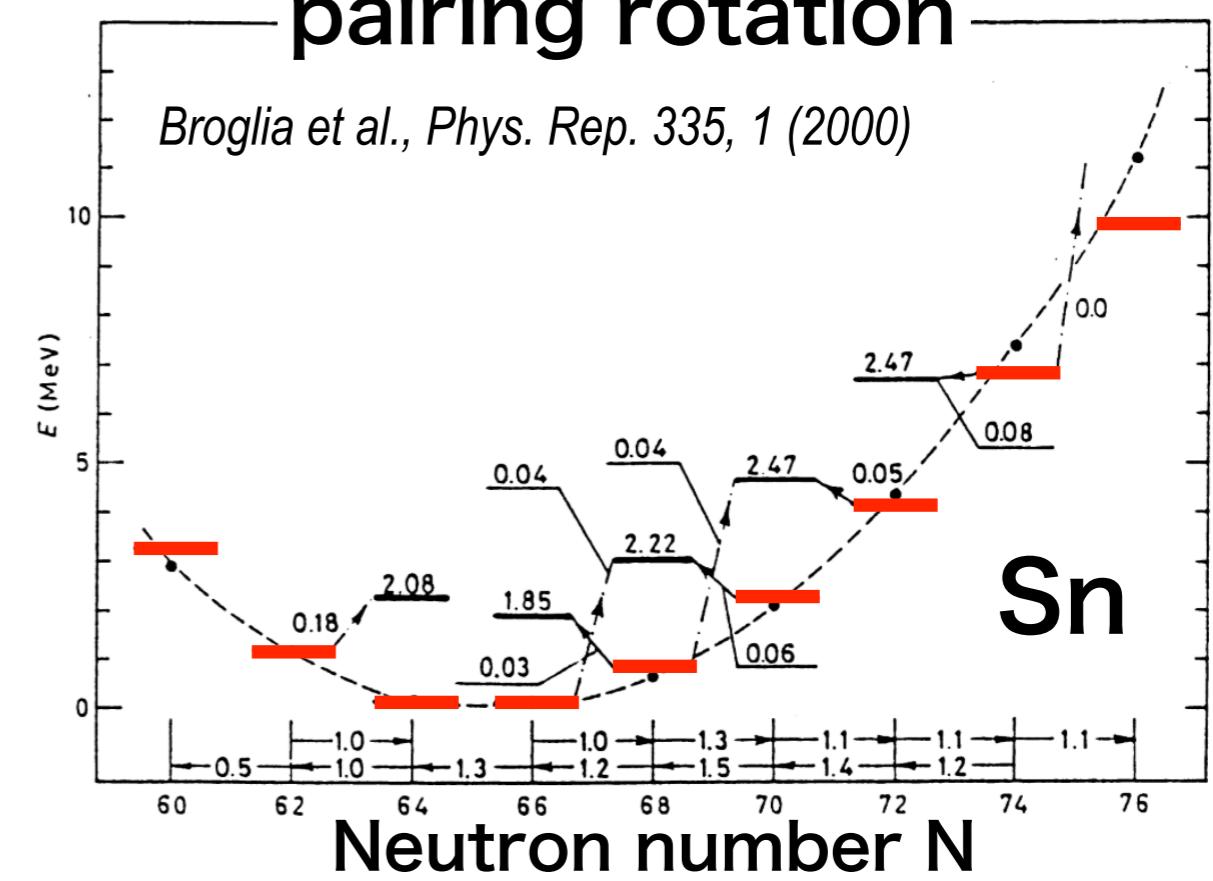
- Binding energy difference
    - $\delta B = \Delta$  for even-even  
 $= 0$  for even-odd  
 $= -\Delta$  for odd-odd

- Collective excitation modes ← Two-nucleon transfer

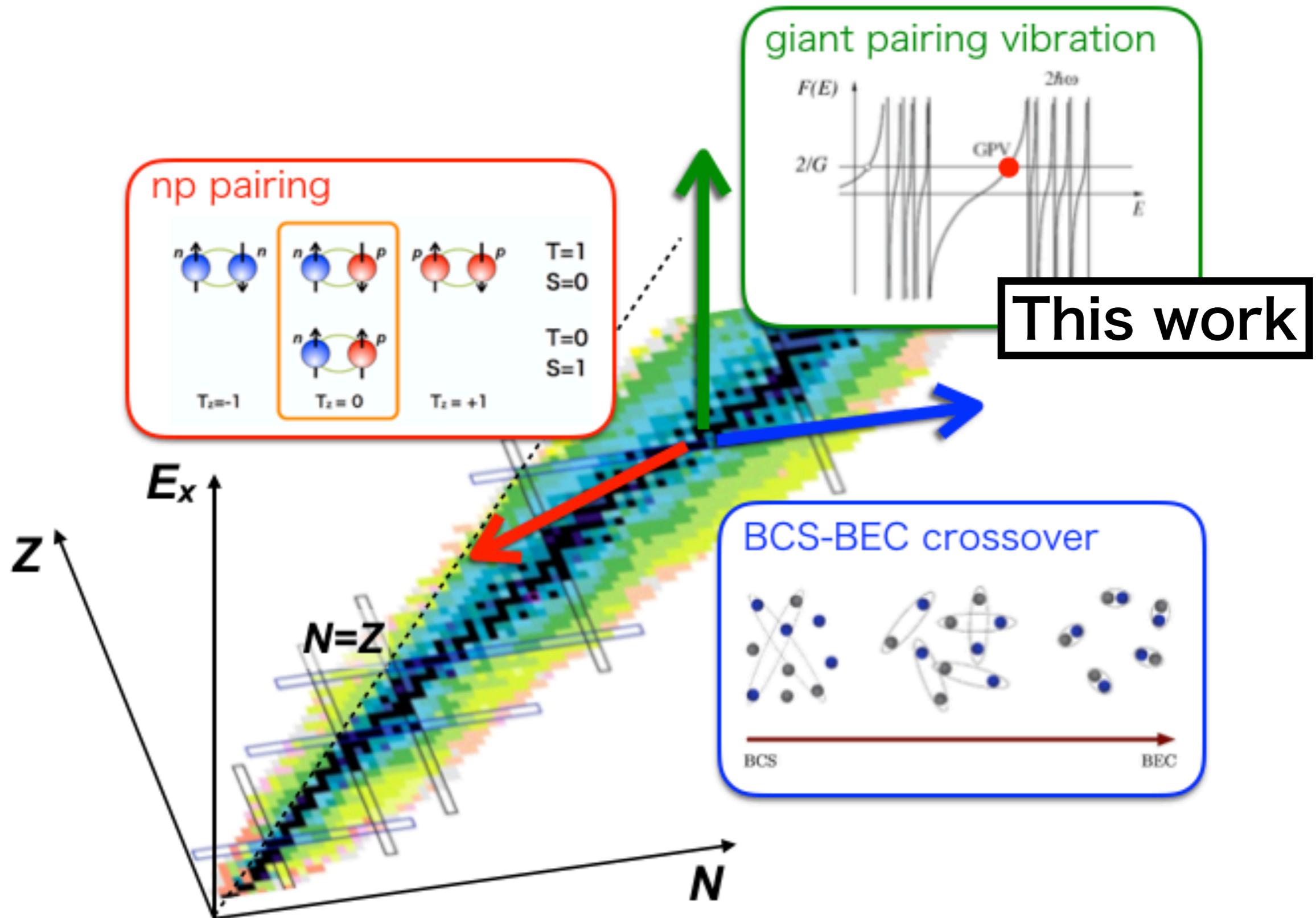
# pairing vibration



# pairing rotation —



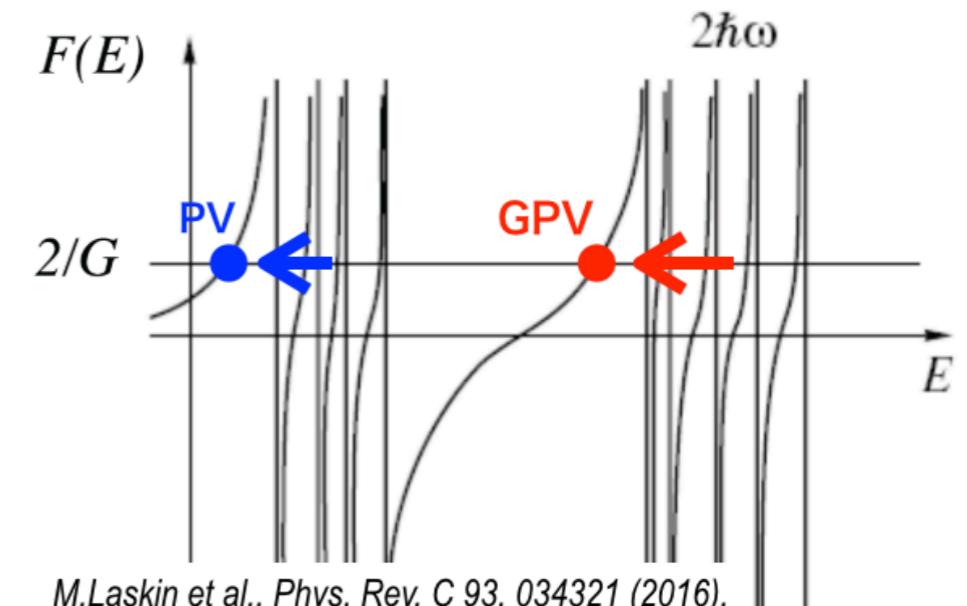
# “Playground” for pairing studies



# 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).

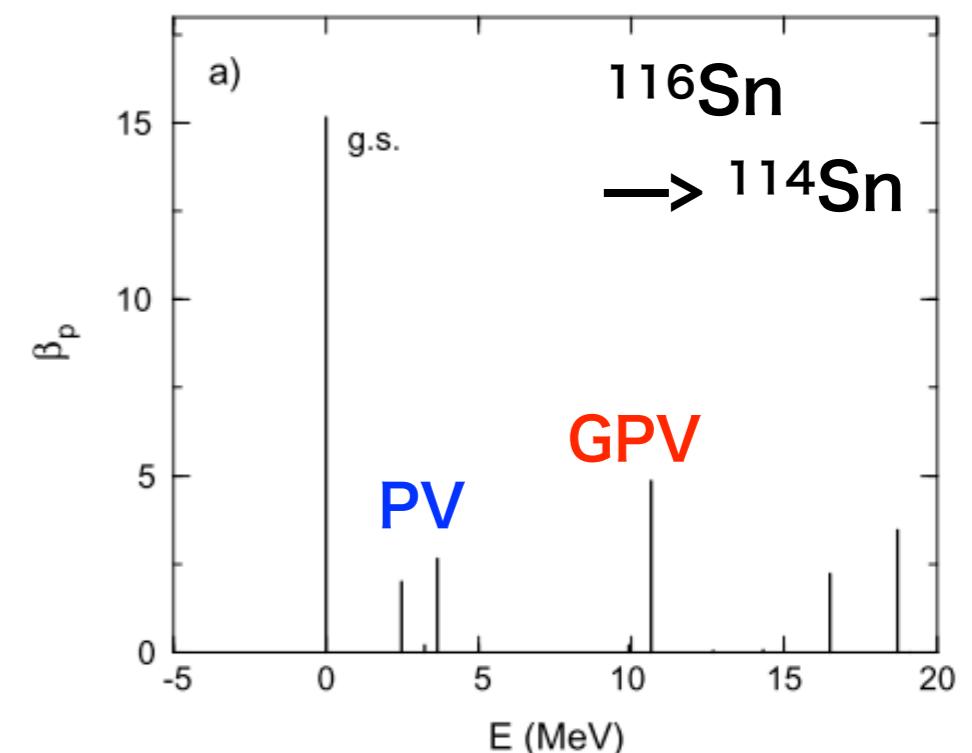
- Excitation of pair across major shells
- Analogy with Giant Resonances
  - GPV : Collective p-p (h-h) excitations
  - GR : Collective p-h excitations



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

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

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



Many experimental attempts  
in several decades,  
but no evidence for GPV

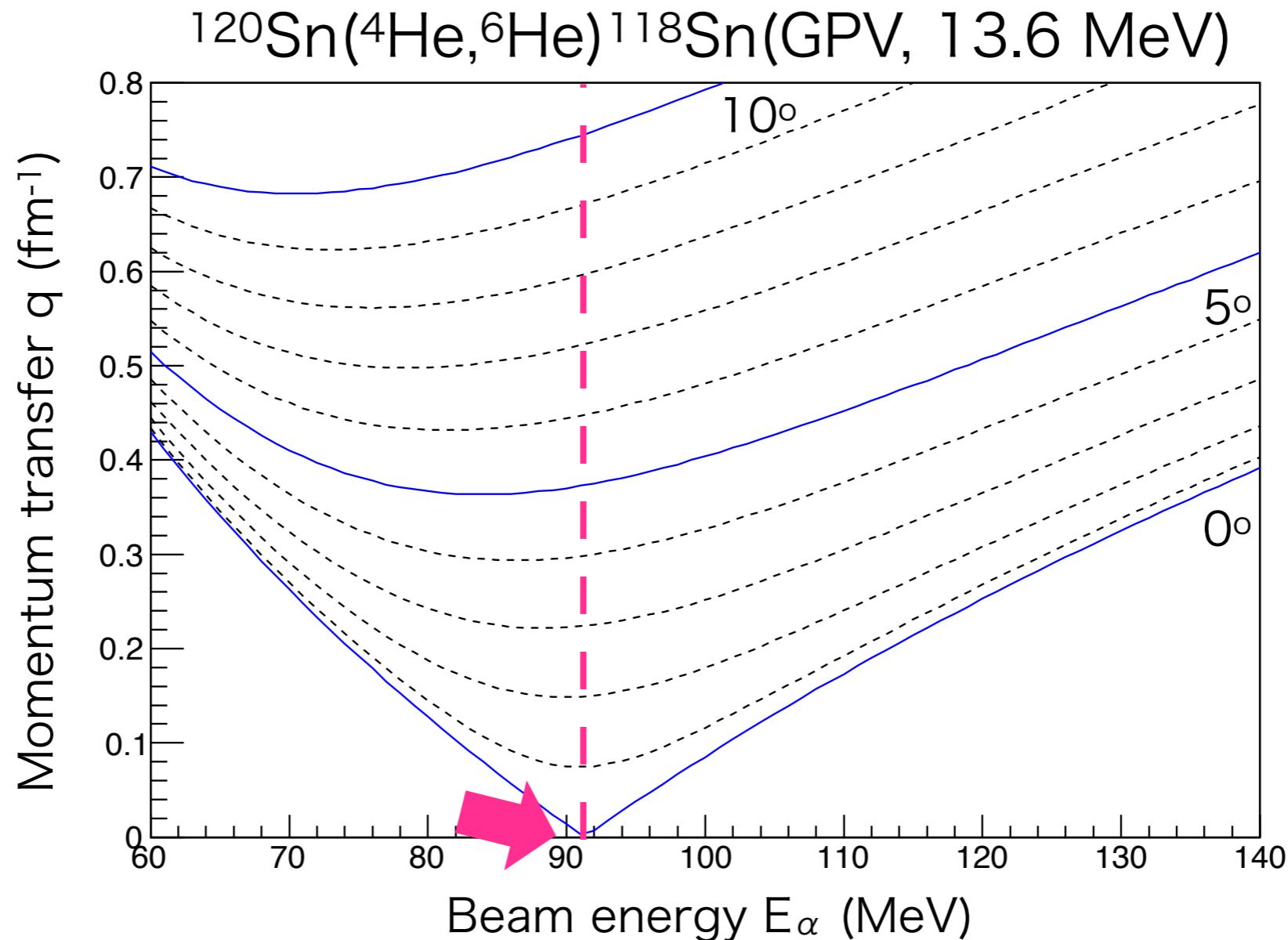
# This work

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- Goal : Confirm existence of GPV
  - Sn isotopes : superfluid nuclei
- Tool : Two-neutron transfer with **recoilless condition**
  - Pair-removal ( ${}^4\text{He}, {}^6\text{He}$ ) reaction
- FY2019 achievements
  - Experimental side
    - Design the measurements at recoilless conditions
  - Theoretical side
    - Theoretical support : Matsuo-san (Niigata)
    - Study properties of GPV

# Recoilless condition

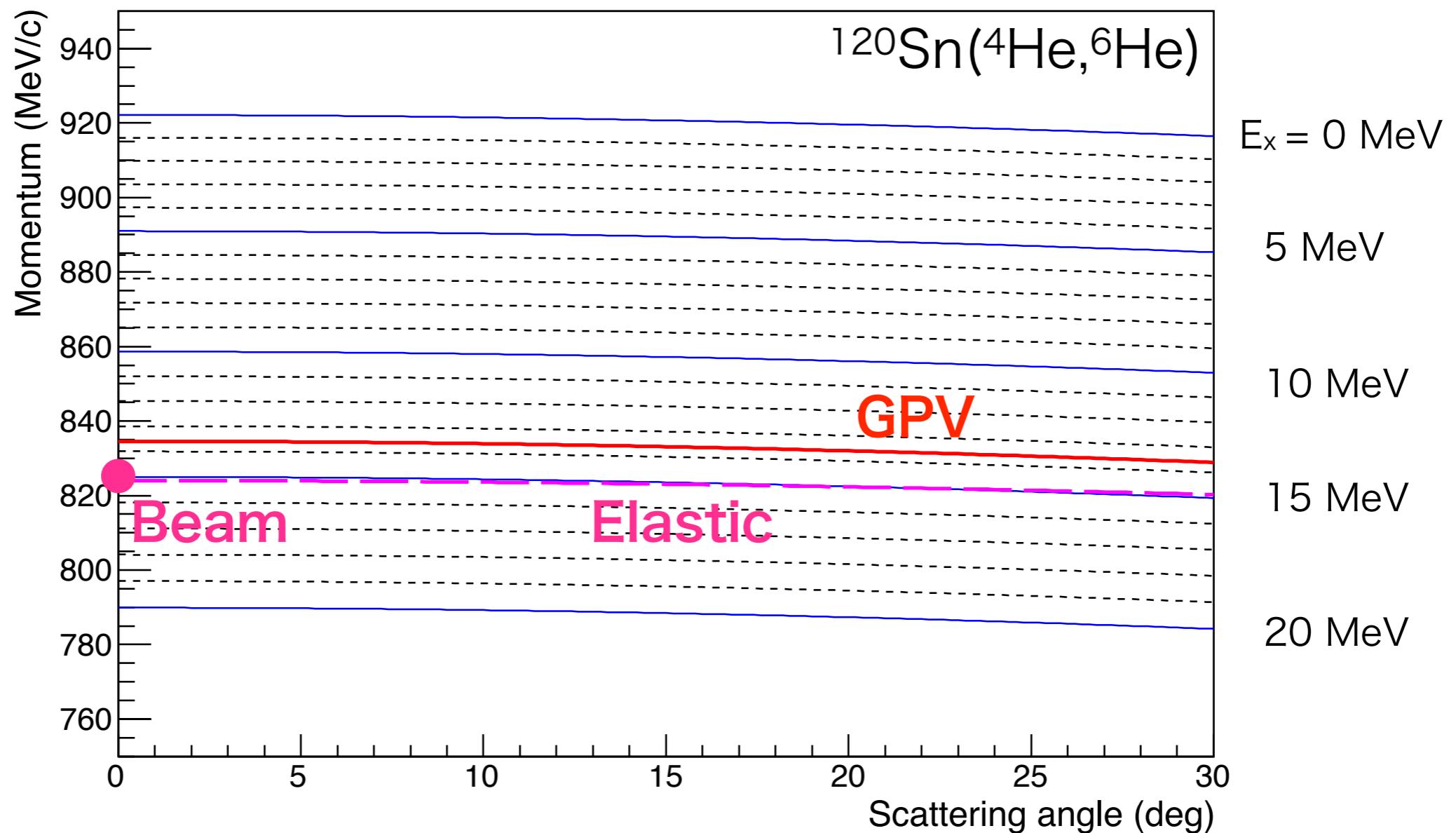
- GPV requires  $L=0$  transfer => **Recoilless condition ( $q = 0$ )**
- Pair removal reaction at  $0^\circ$  and appropriate energy



# Recoilless condition

- Experimental problem : Background from beam & elastic

$P_{^6\text{He}, \text{GPV}} \sim P_{^4\text{He}, \text{beam\&elastic}}$



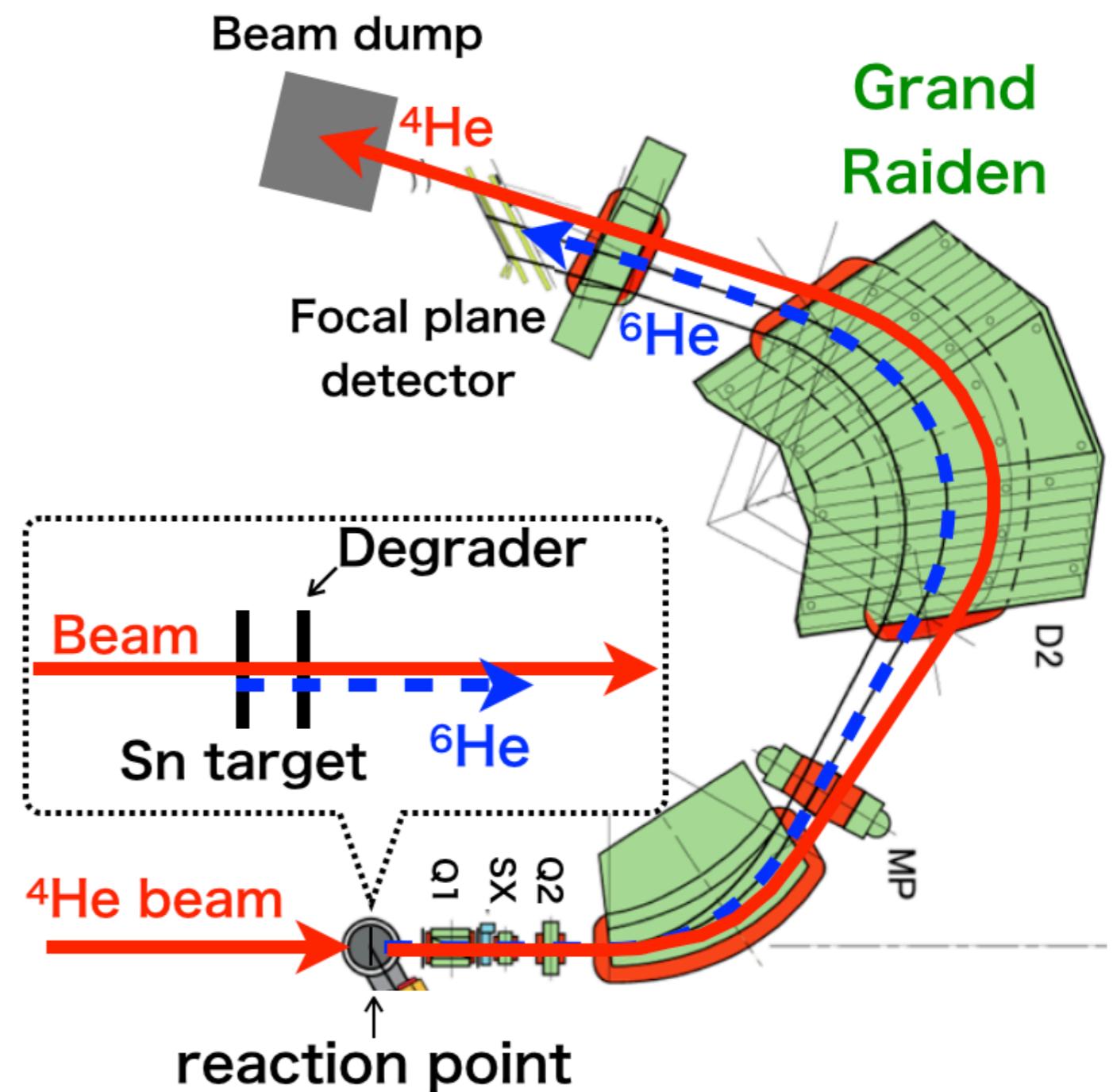
# "New" experimental setup

- Particle separation using degrader + spectrometer

- Before deg.
  - $P_{^6\text{He}, \text{GPV}} \sim P_{^4\text{He}, \text{beam\&elastic}}$
  - $\beta_{^6\text{He,GPV}} < \beta_{^4\text{He,beam\&elastic}}$
- After deg.
  - $\Delta E \propto Z^2 / \beta^2$
  - $\rightarrow P_{^6\text{He}, \text{GPV}} < P_{^4\text{He}, \text{beam\&elastic}}$

- Sn( $^4\text{He}, ^6\text{He}$ ) at RCNP

- $^4\text{He}$  beam @ 90 MeV
- Sn target ( $A=116-124$ )  
10 mg/cm<sup>2</sup>
- Grand Raiden, 0° mode
- Al degrader 10 mg/cm<sup>2</sup>  
 $\rightarrow \sim 1\%$  separation



# Theoretical study for GPV

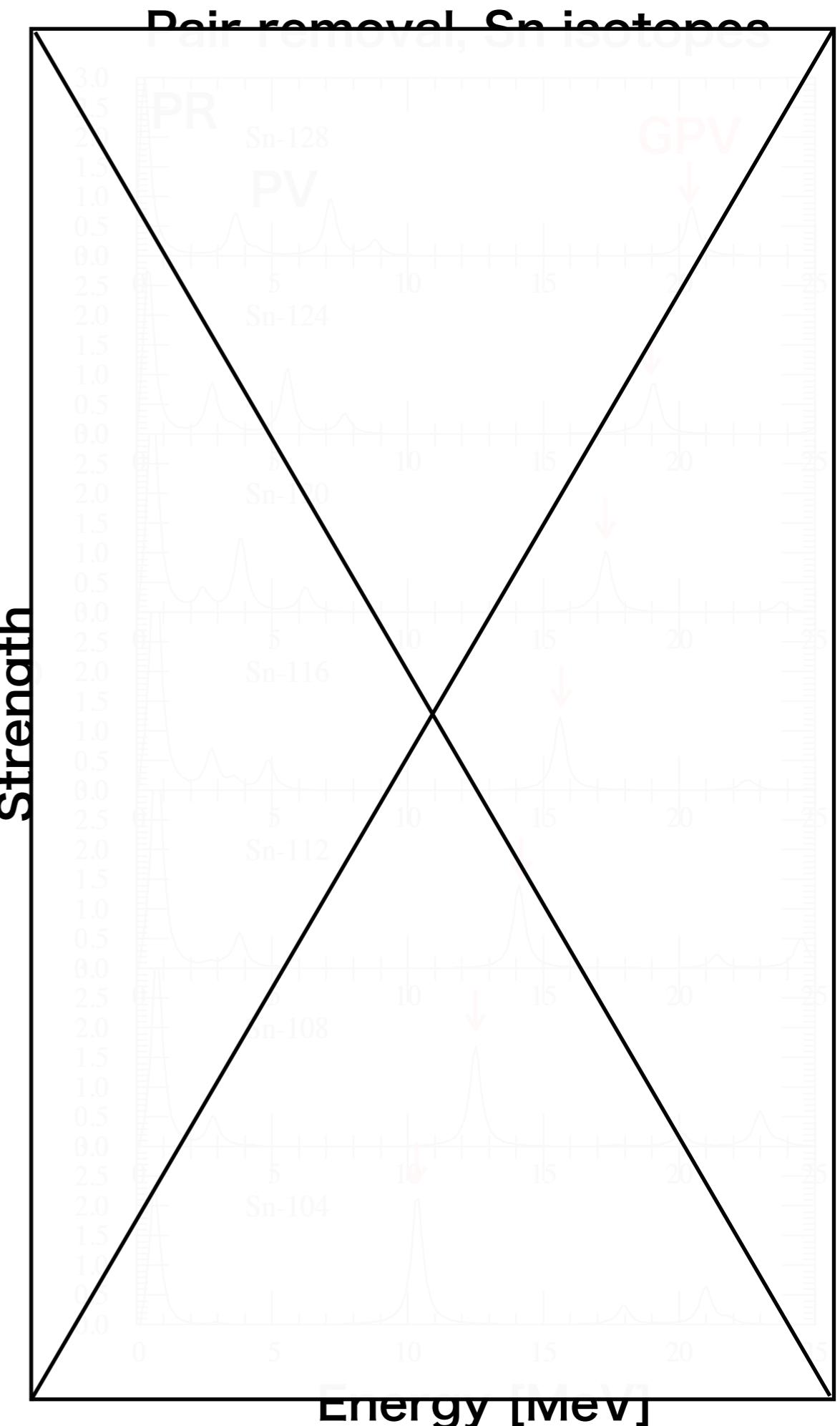
- HFB+QRPA calc. by Matsuo-san

- GPV
  - Drastically changed along isotopic chain (energy, strength)

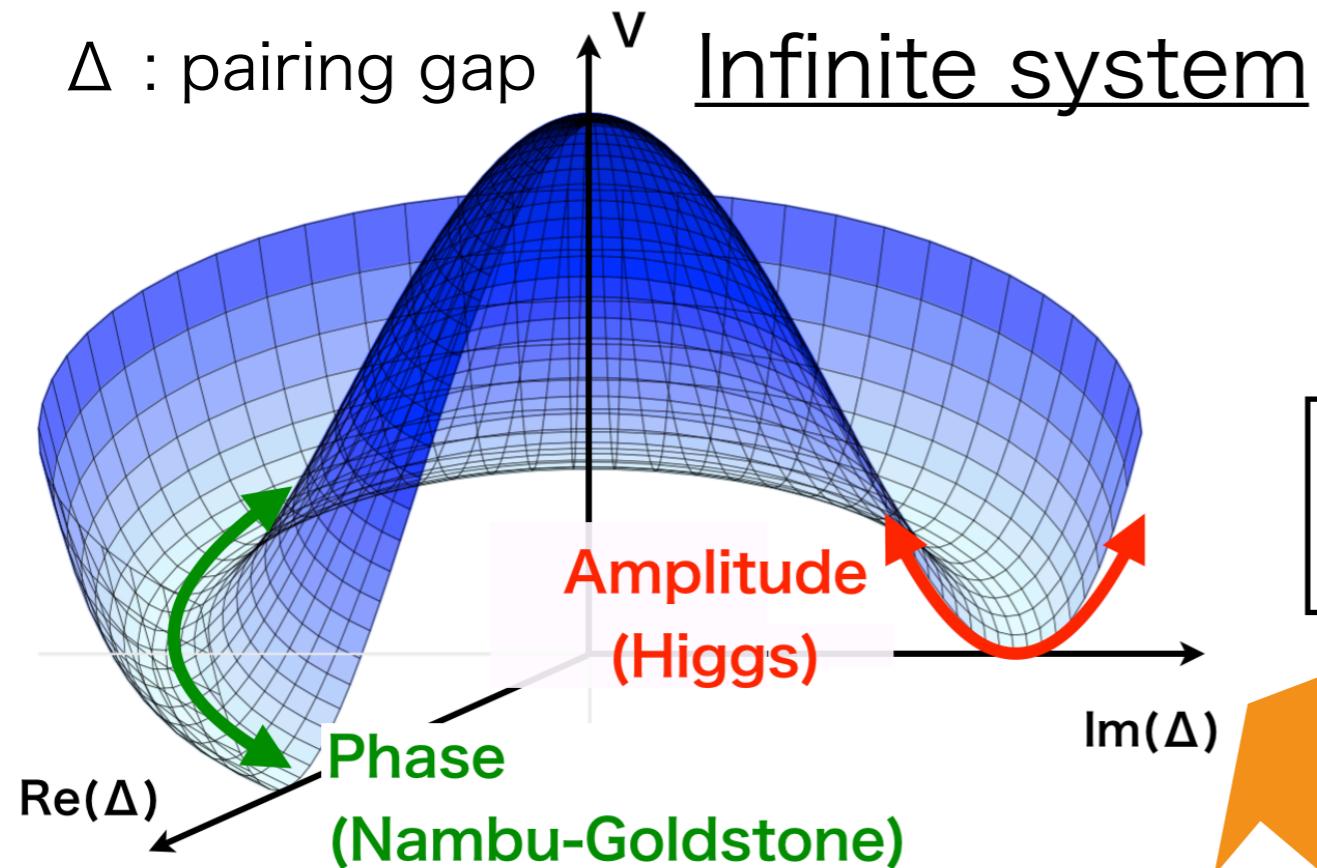
Different from GR

- Low-lying PV
  - Act as counterpart of GPV ?

PV and GPV  
are essentially the same ?



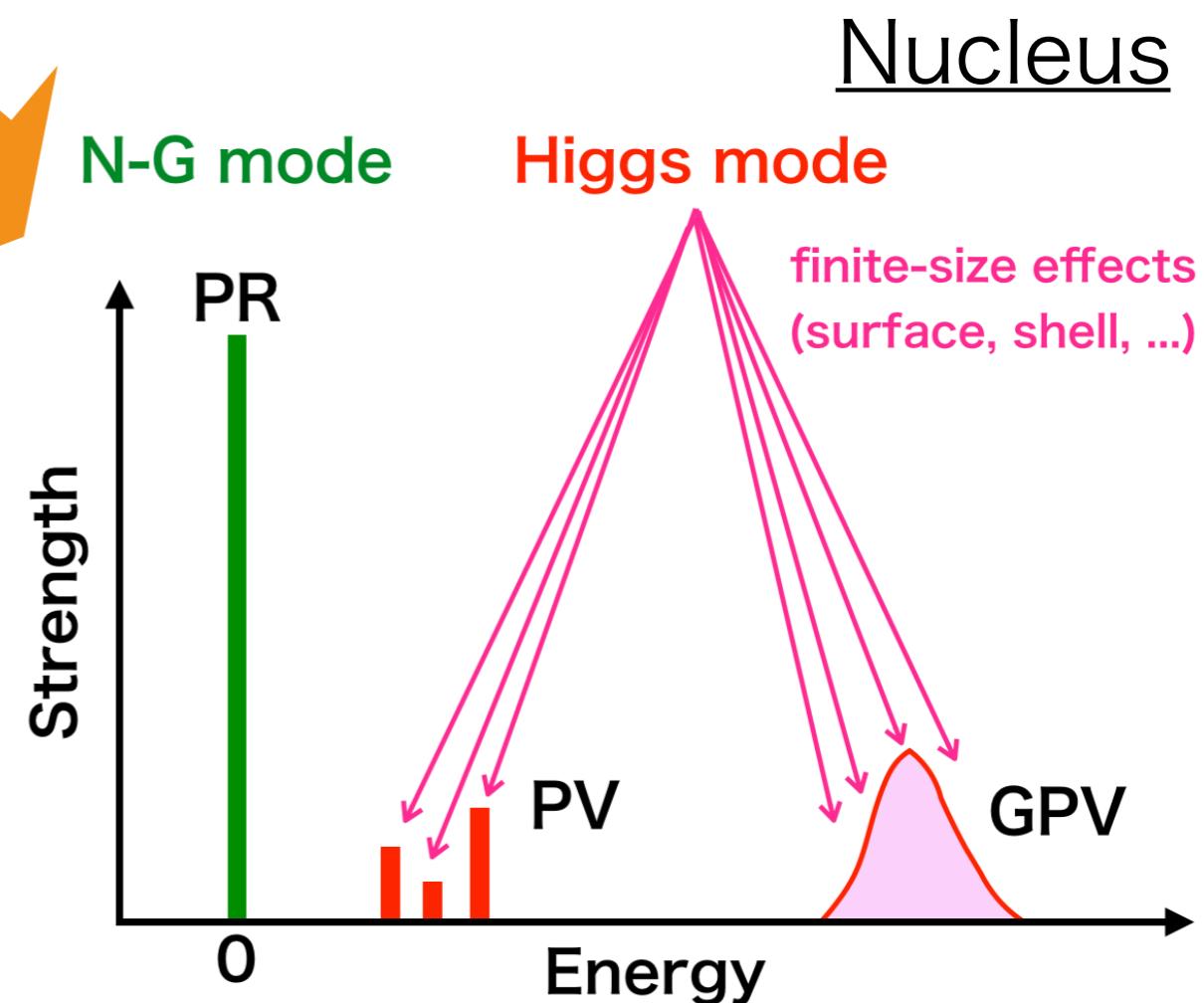
# What is GPV ?



N-G mode : PR

Higgs mode : PV + GPV ?

GPV is a fragment  
of Higgs mode ?  
Experimental research  
is desired.



# Summary

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- GPV might be a key to understand the mechanism of pair condensation.
- To populate GPV selectively,  
two-neutron transfer measurements at recoilless kinematics are planned.
- Plan in FY2020
  - Experimental side
    - Submit a proposal to RCNP (1 or 2 Sn isotopes)
      - Recoilless kinematics (w/ degrader)
      - Small momentum transfer ( $q \sim 0.2 \text{ fm}^{-1}$ ) kinematics (w/o degrader)
    - Experiment @ CYRIC
      - reaction mechanism of two-neutron transfer
  - Theoretical side
    - Theoretical support : Matsuo-san (Niigata)
    - Properties of GPV