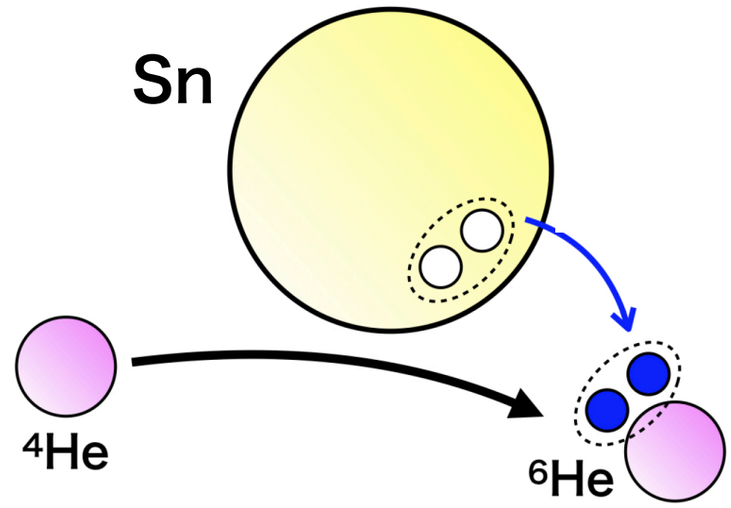
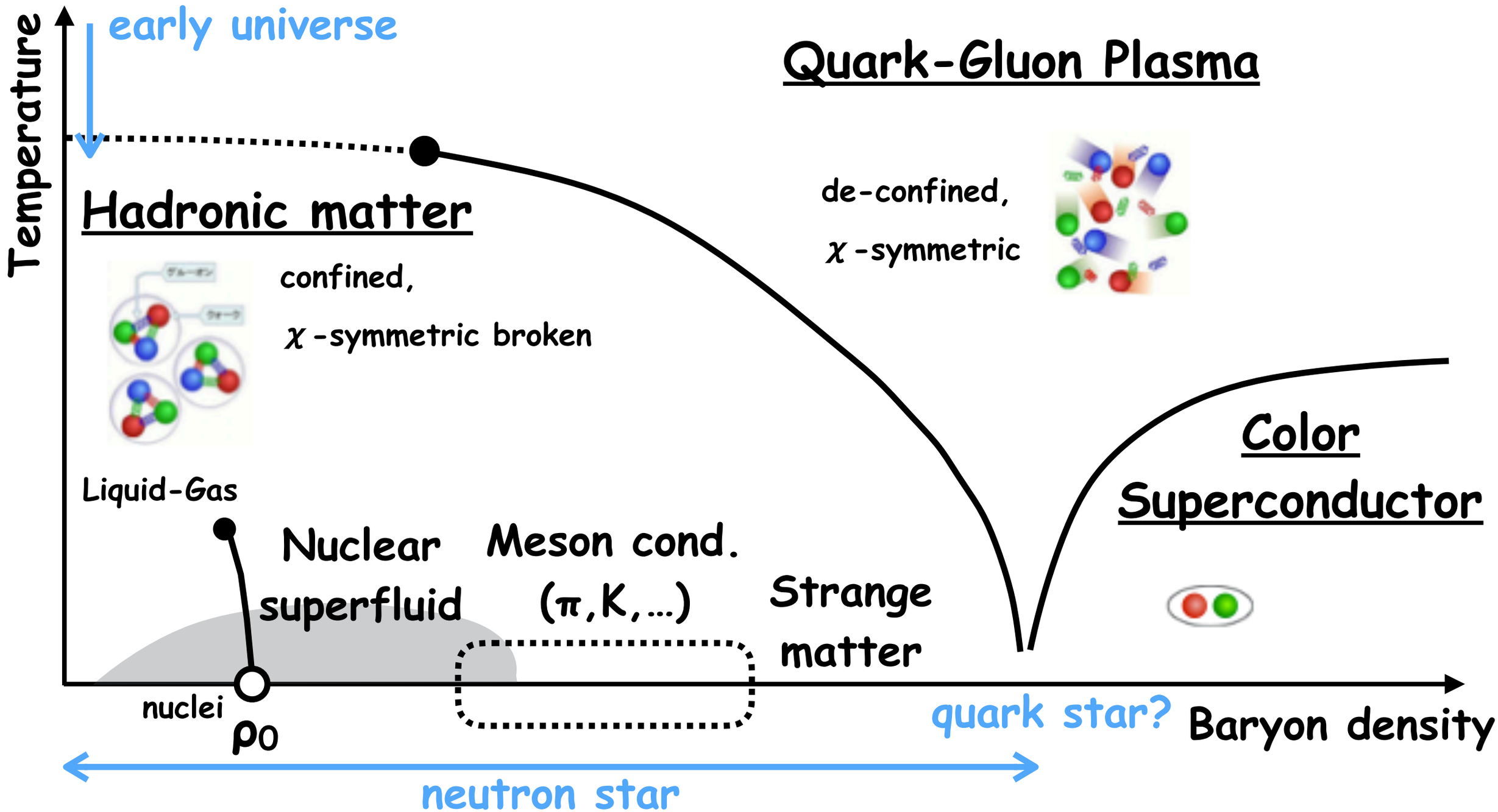


Study of pair vibrations as an elementary nuclear mode using the (α,^{6}He) reaction

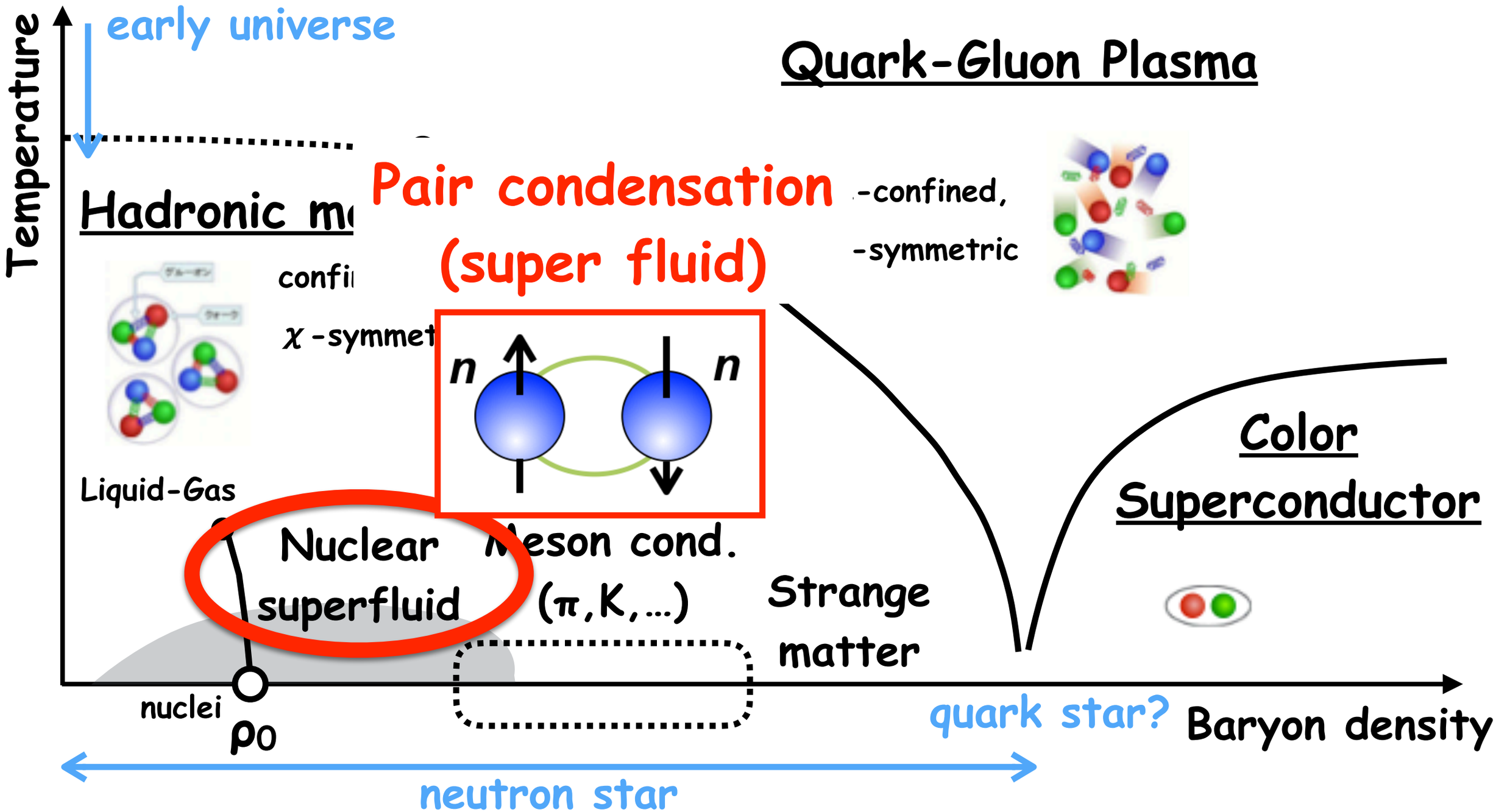
Masanori Dozono
Kyoto University

第8回クラスター階層領域研究会， 9-11 February，2023

QCD phase diagram



QCD phase diagram



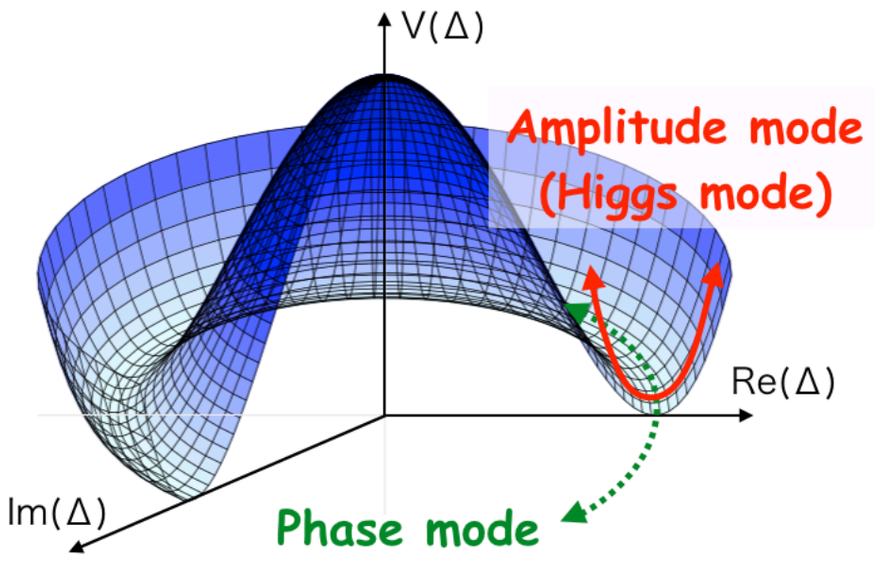
Nuclear matter vs Finite nuclei

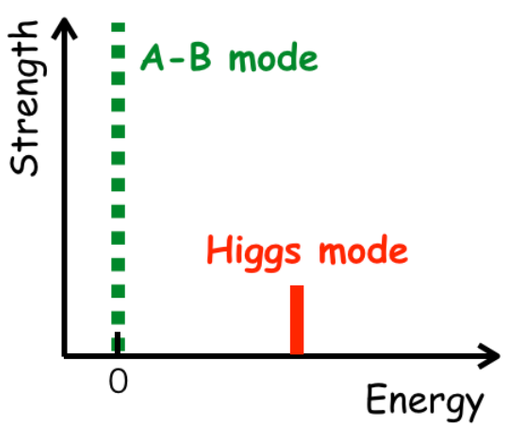
Nuclear matter

Pair condensation

Gauge symmetry breaking (U(1))

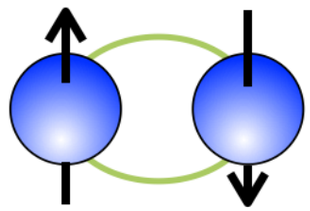
$$\psi \to \psi e^{i\theta} \quad \Delta = \langle \psi\psi \rangle \to \Delta e^{2i\theta}$$





A-B mode

Higgs mode



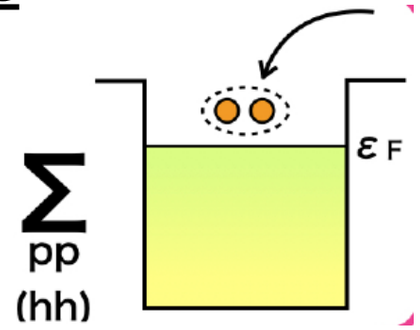
Nuclear pairing

Finite nuclei

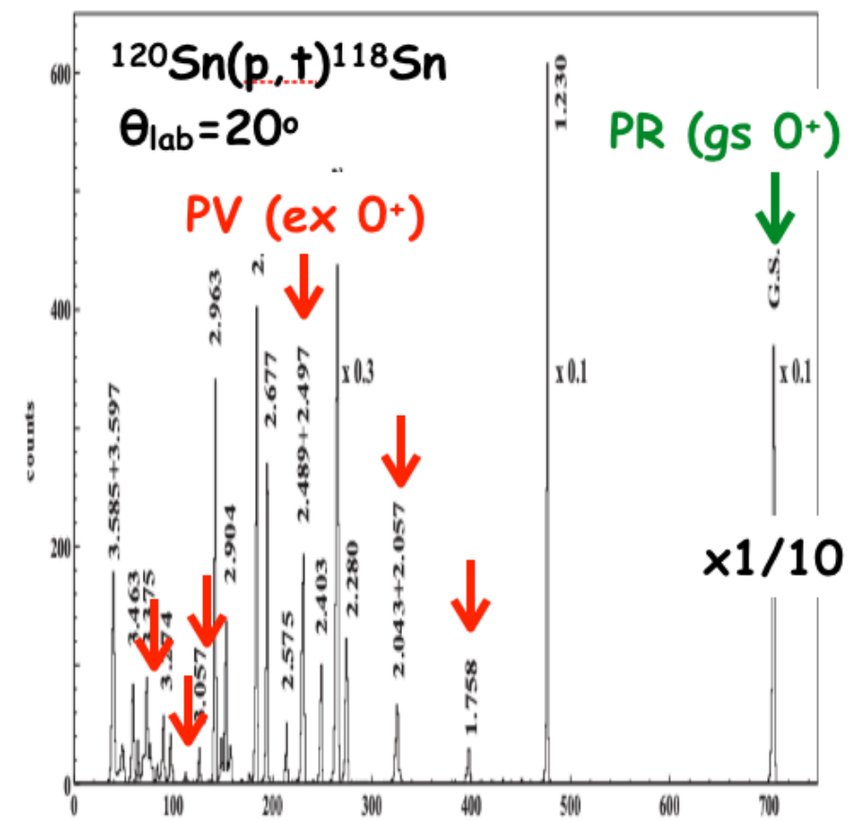
Nuclear responses to pair transfer

pair rotation

pair vibration



P.Guazzoni etal.,
PRC78,064608(2008)



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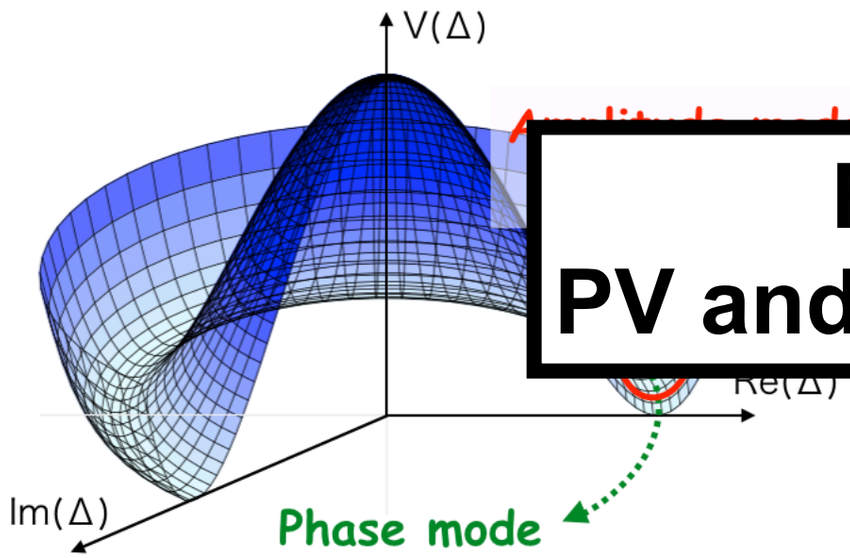
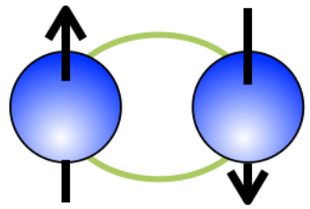
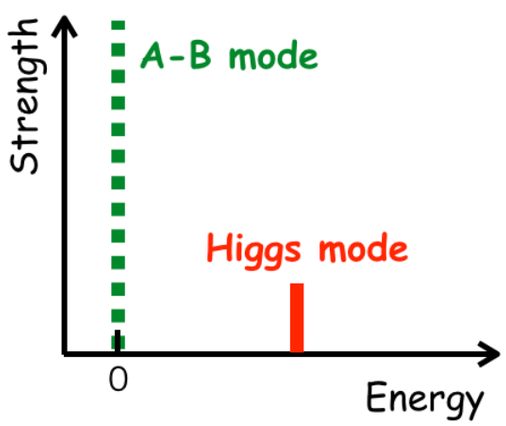






A-B mode

Higgs mode

Relation between PV and Higgs mode is unclear

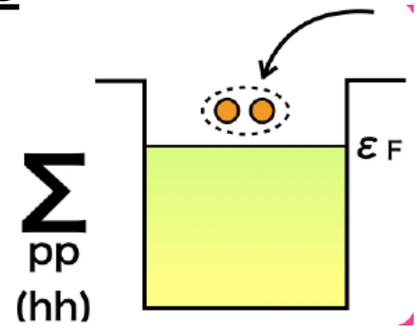
pairing

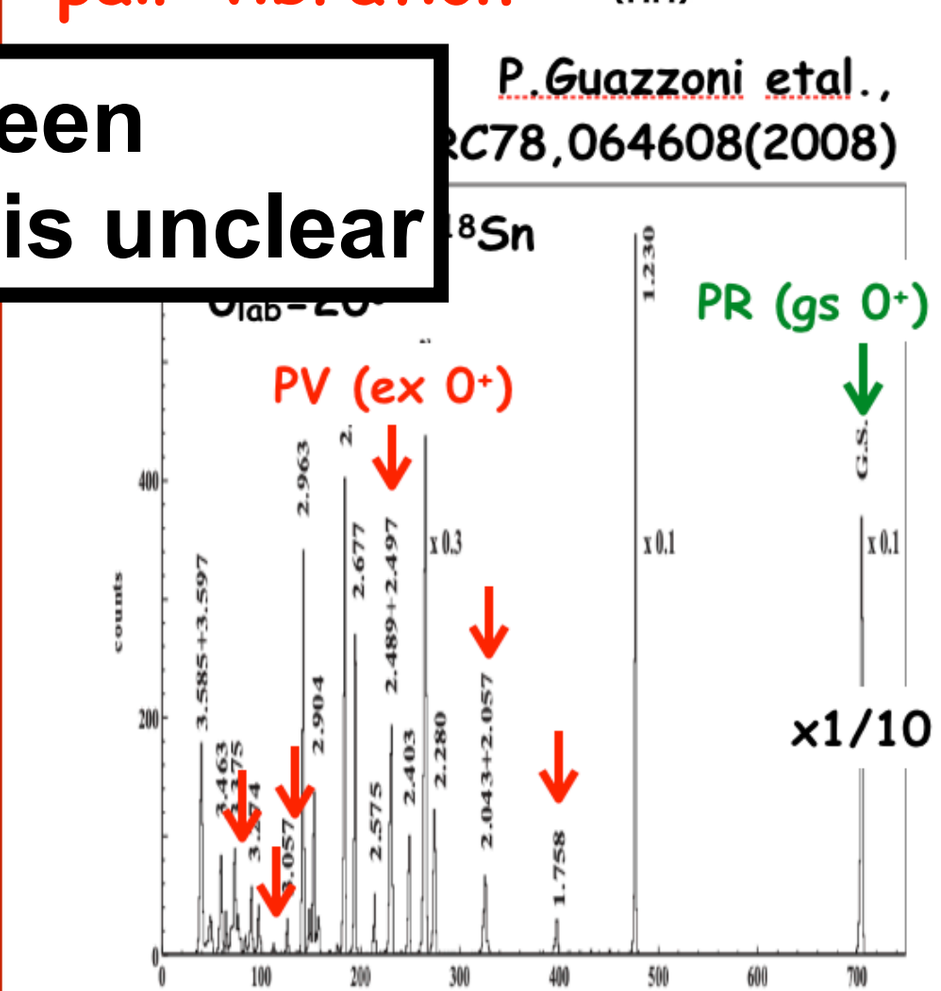
Finite nuclei

Nuclear responses to pair transfer

pair rotation

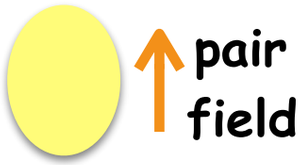
pair vibration





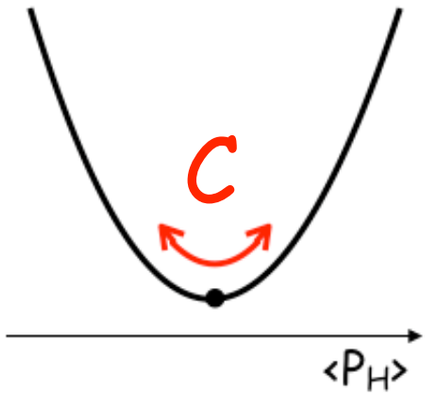
New idea : Pair-field static polarizability

- Static polarizability for $P_H = P_{ad} + P_{rm}$



$$\alpha_{P_H} = 2M_{-1}^{P_H} = 2\int_0^\infty d\omega \frac{S_{P_H}(\omega)}{\hbar\omega}$$

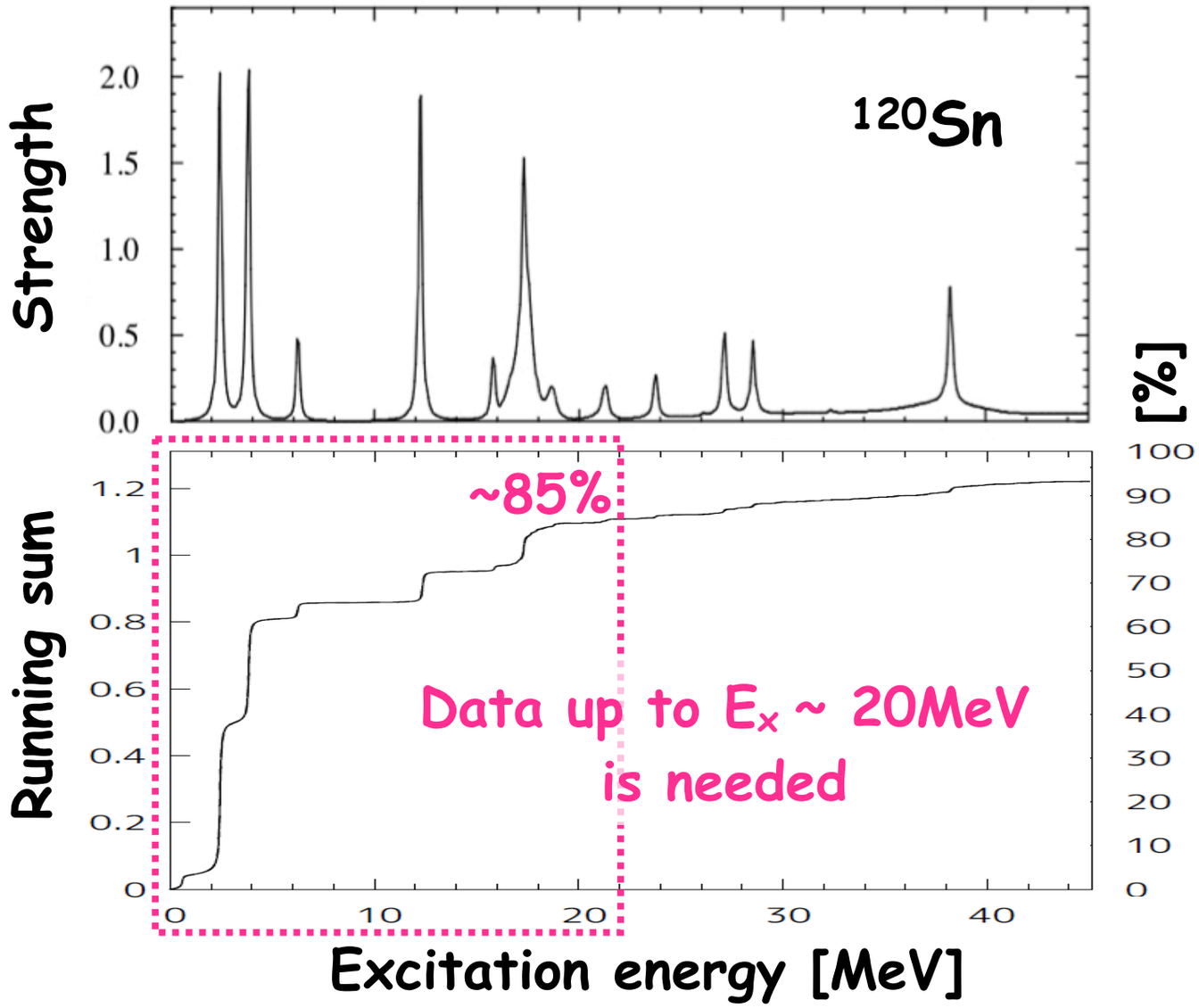
- Pair energy curvature



$$C_{cond} = \frac{1}{\alpha_{P_H}}$$

cf Hellman-Feynman theorem

By M.Matsuo (Niigata)



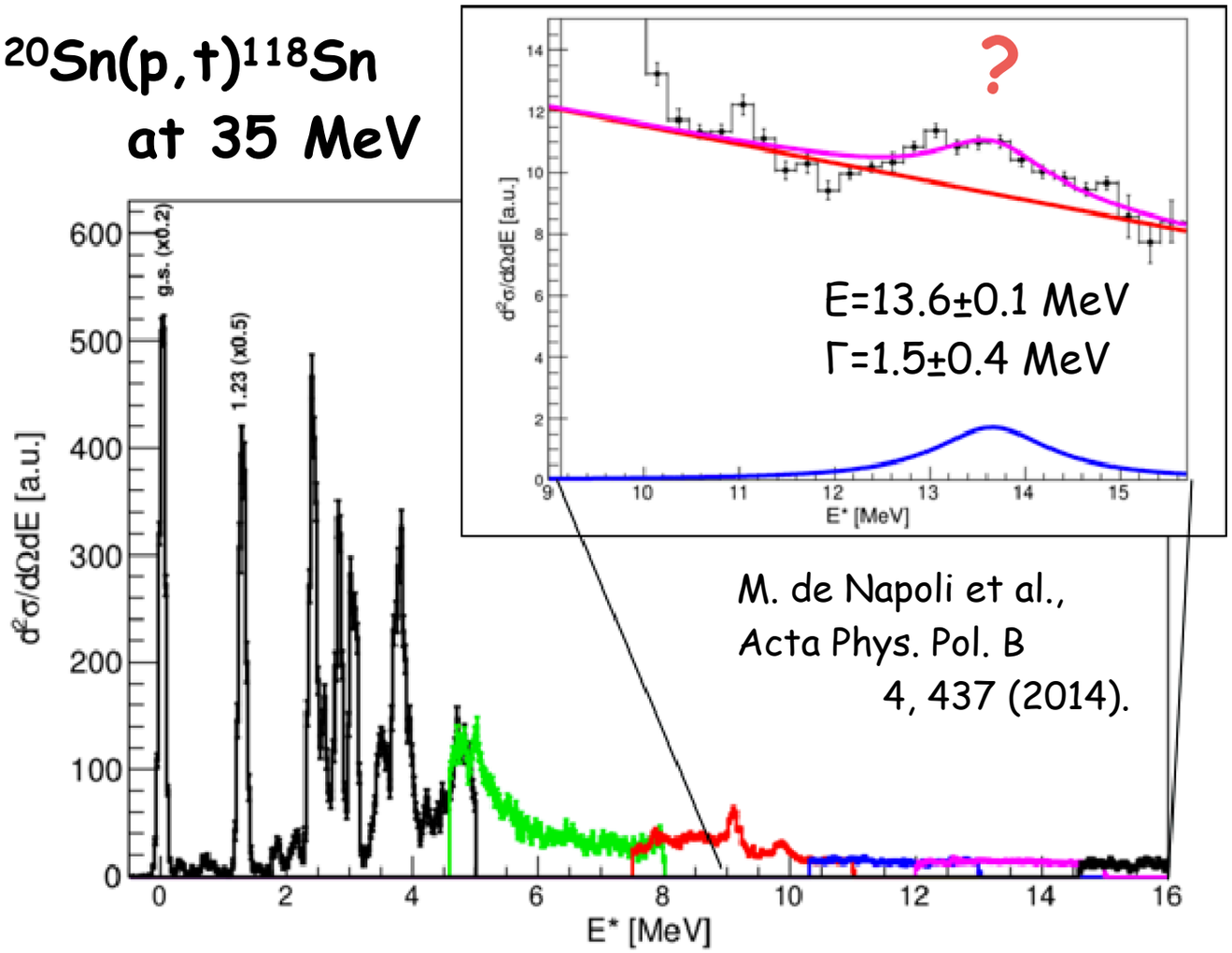
- Higgs ~ Pair vib.

- C can be evaluated from systematic data for pair vib.

Experimental attempts for High-lying PV

- **Sn(p,t) at 42MeV** G.M.Crawley et al., PRL 39, 1451 (1977)
- **^{120}Sn,^{208}Pb(p,t) at 50,60MeV** B. Mouginot et al., PRC 83, 037302 (2011)
- **^{120}Sn(p,t)^{118}Sn at 35MeV** M. de Napoli et al., Acta Phys. Pol. B 4, 437 (2014).

^{120}Sn(p,t)^{118}Sn at 35 MeV



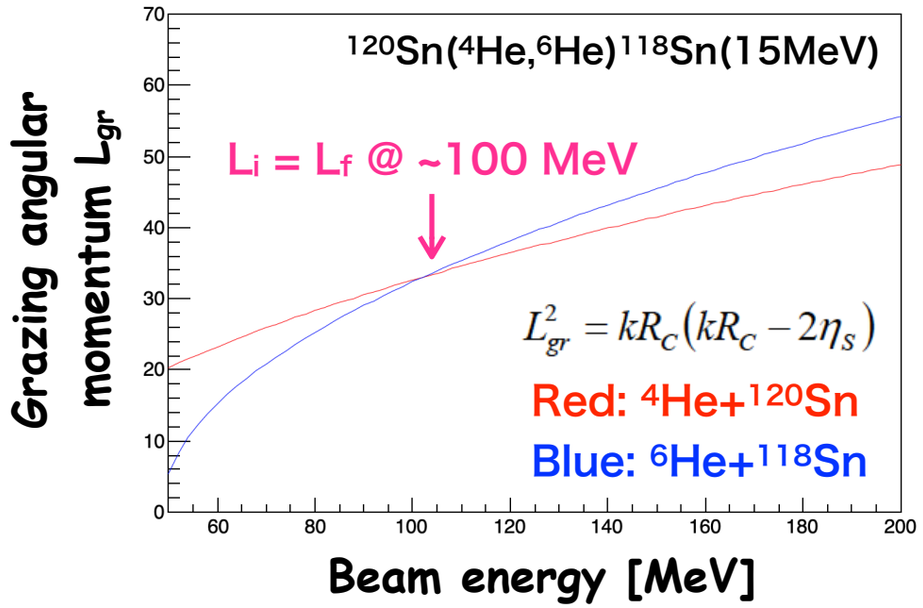
Existence of PV at ~13MeV is indicated but not conclusive…

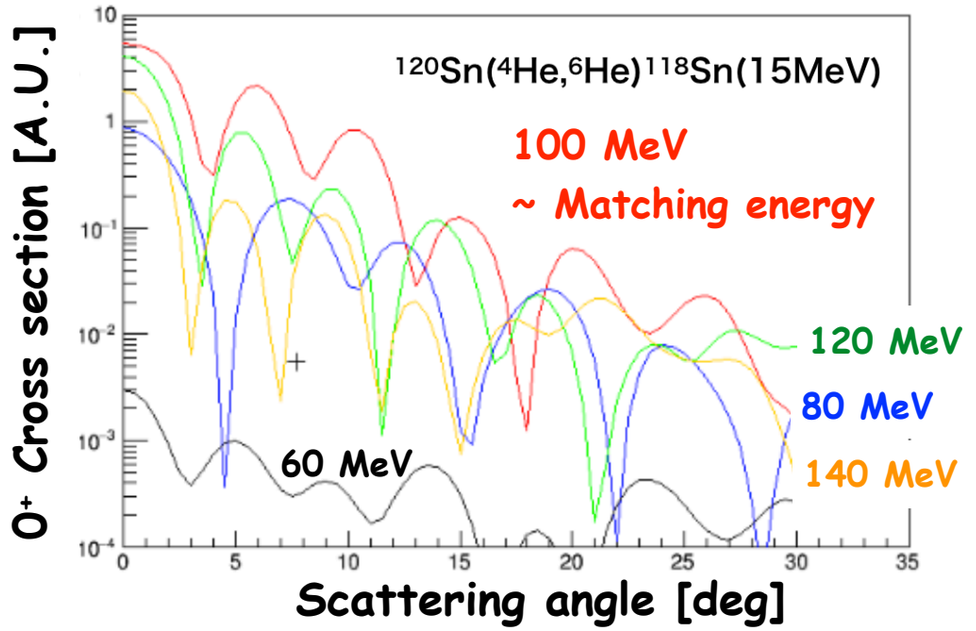
A more efficient tool is required

(α,^{6}He) reaction

A probe to high-lying pairing modes !

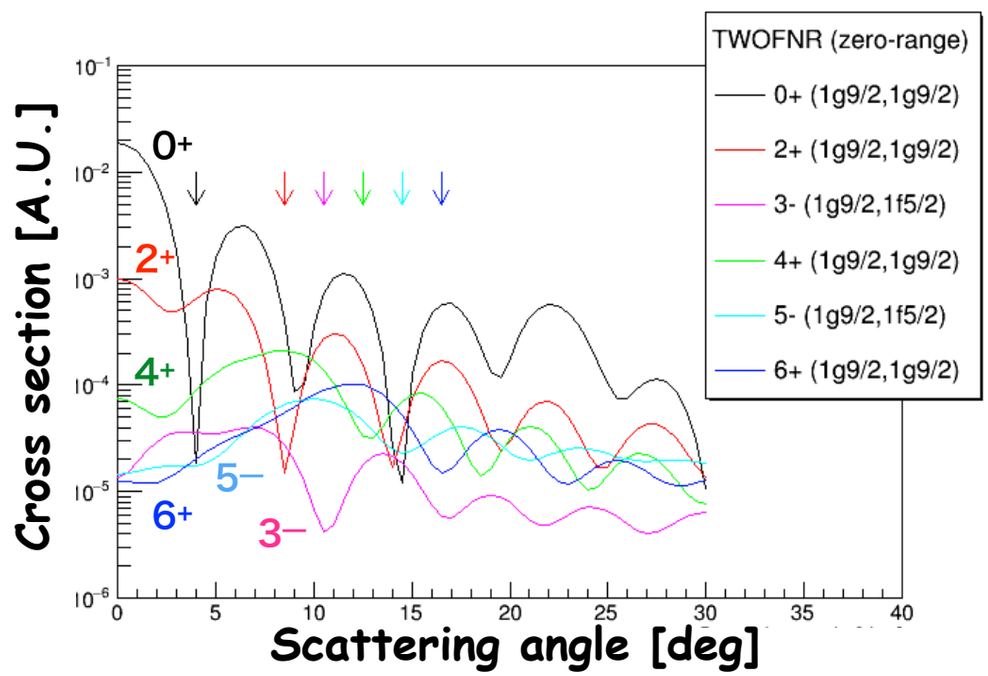
- L=0 transfer matching —> Increase population of high-lying 0^{+} modes





- Sharp diffraction pattern of angular distribution
(due to strong absorbed feature)

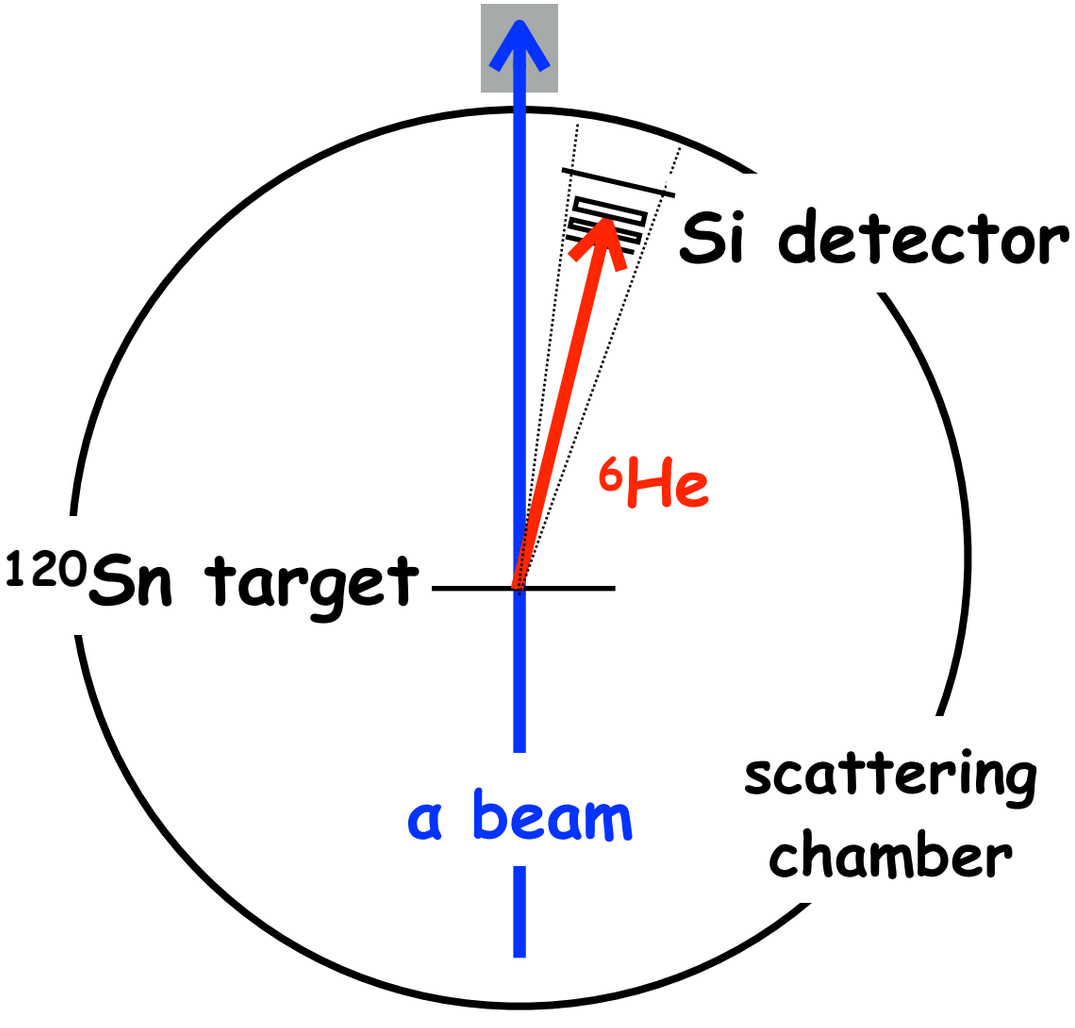
—> Reliable J^{π} assignment
using MD analysis

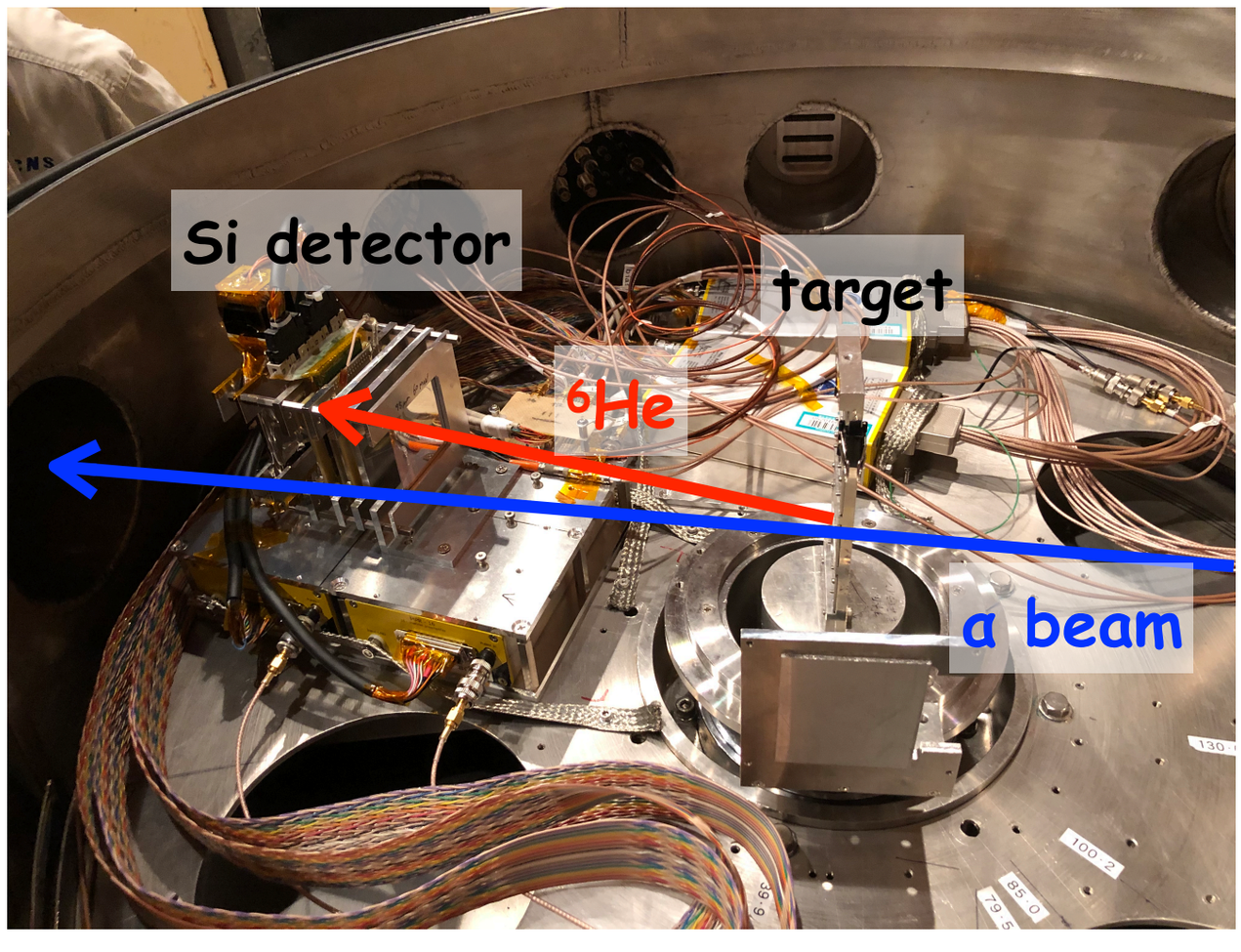


Test experiment @ CYRIC (Tohoku)

- $^{120}Sn(\alpha,^{6}He)^{118}Sn$
- Target : ^{120}Sn, 3mg/cm2
- Beam : α, 100MeV, ~1nA
  (L=0 Matching at E_x~15MeV)

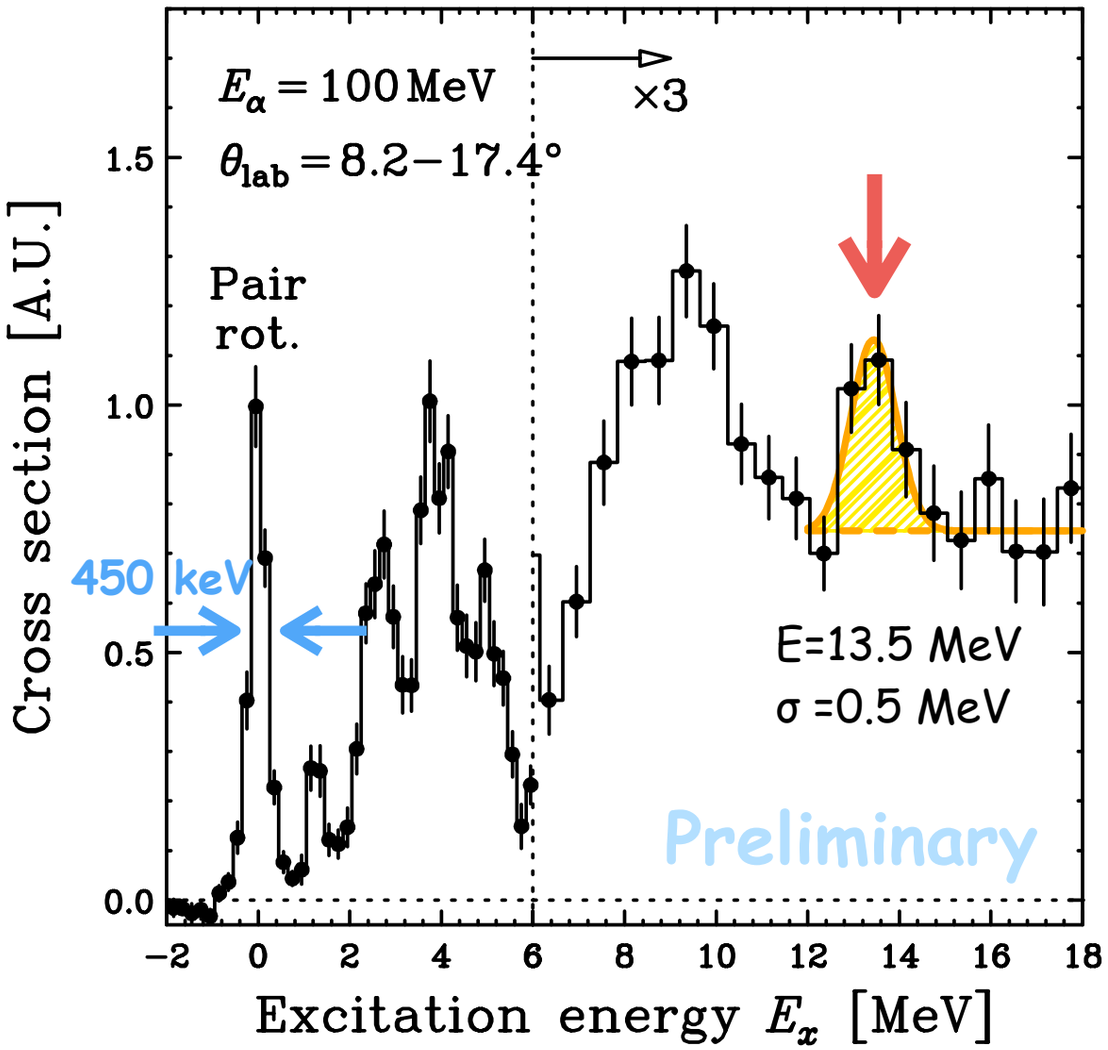
- ^{6}He detection
  - Si x 3 + VETO of elastic
  - PID (ΔE-E method)
  - θ_{6He} = 8° — 18° with 0.6° step





E_x spectrum

^{120}Sn(α,^{6}He)^{118}Sn at 100MeV



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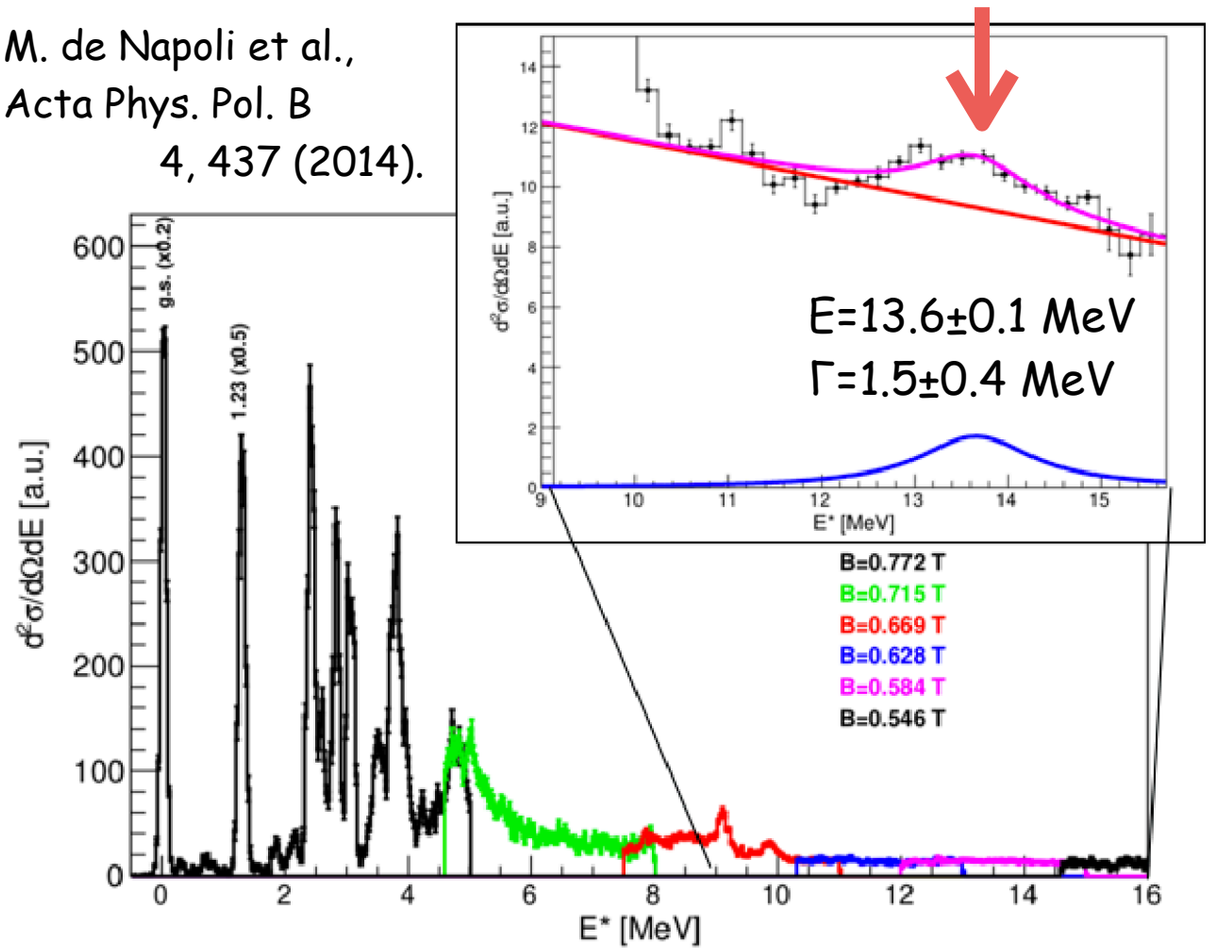
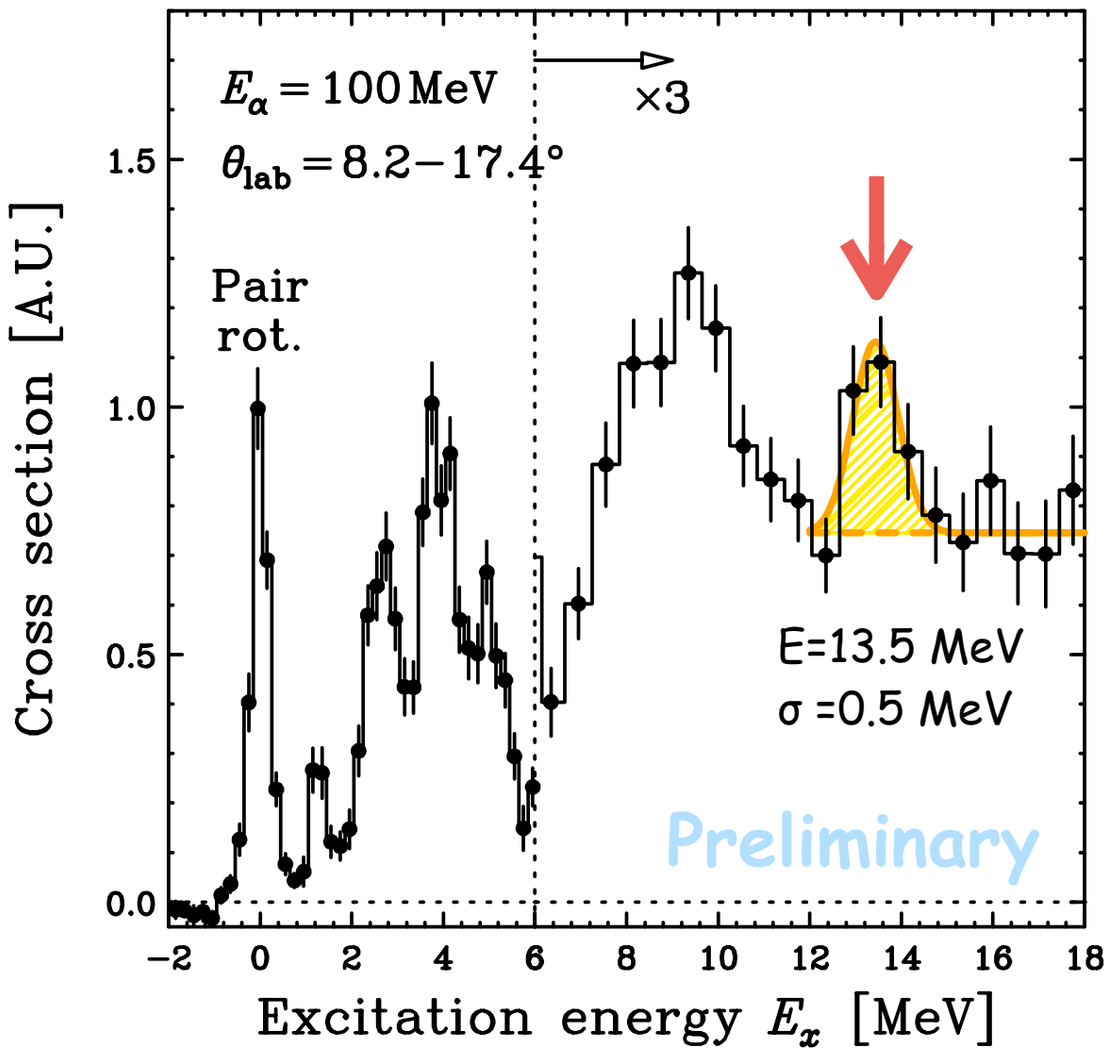


We found a clear peak at ~13 MeV

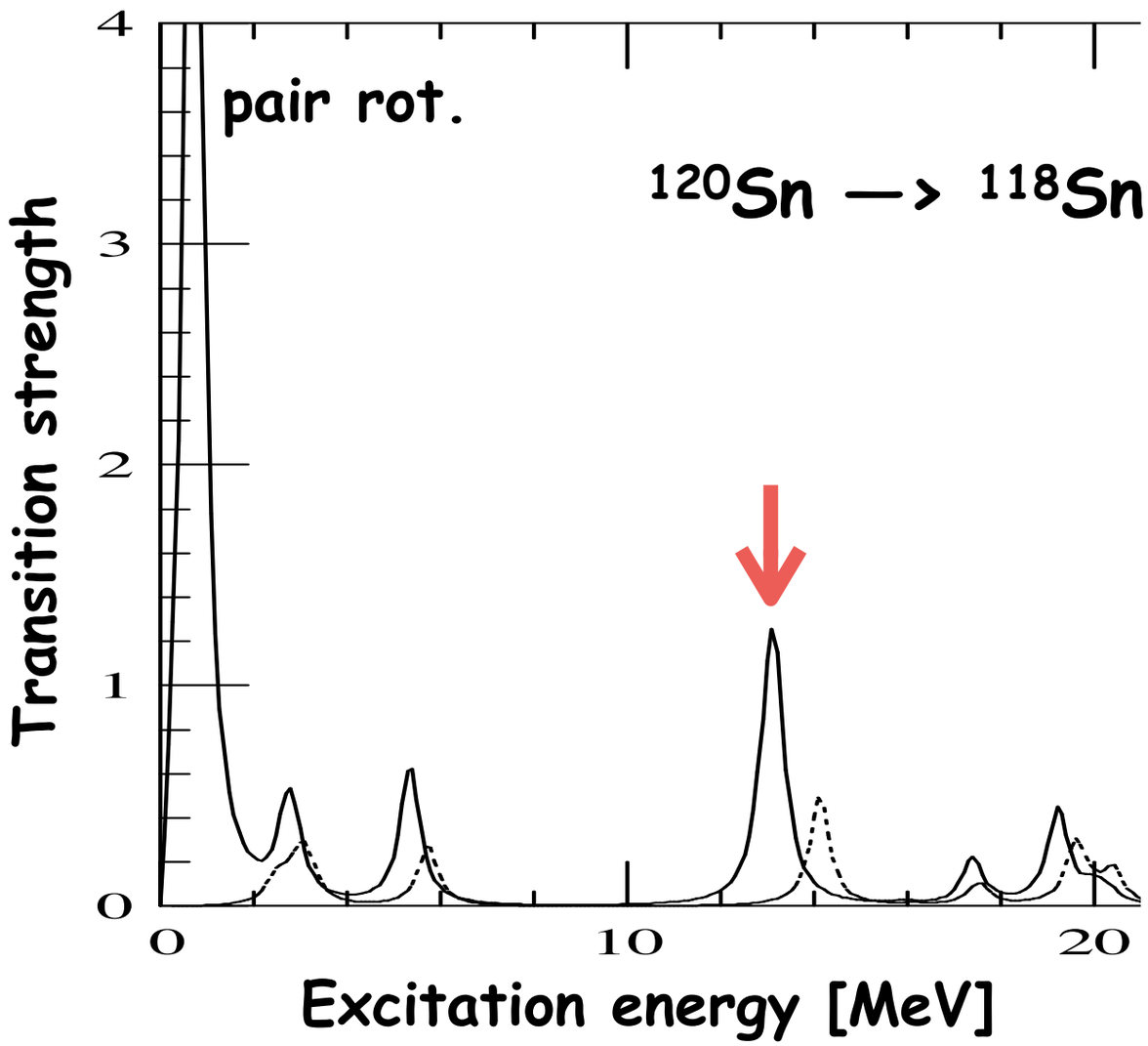
—> Effectiveness of (α,^{6}He)

E_x spectrum

^{120}Sn(α,^{6}He)^{118}Sn at 100MeV



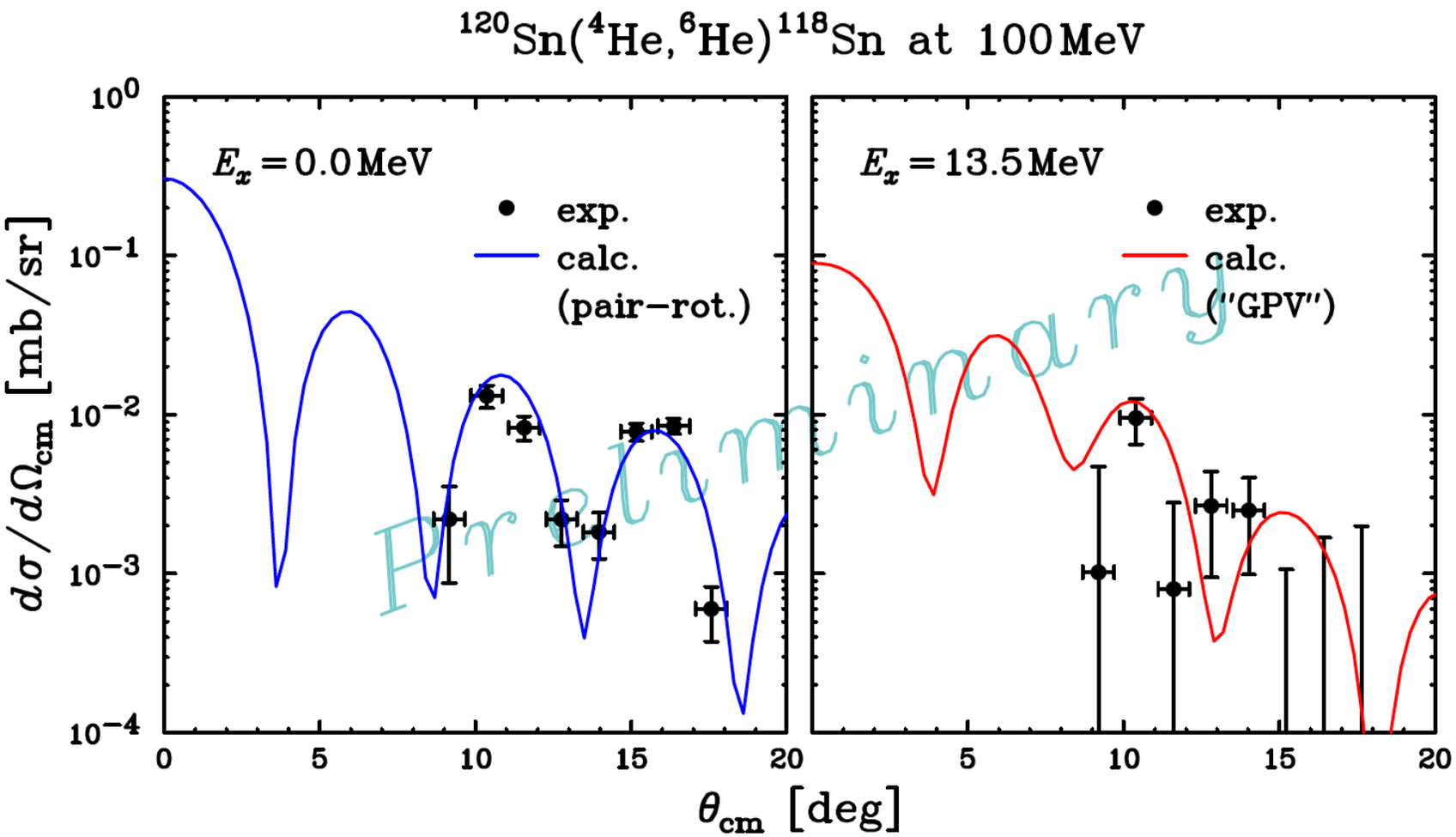
HFB+QRPA by Matsuo-san



Candidate for high-lying PV ?

Comparison with DWBA results

- Normalization factor : Determined by g.s.
  —> Exp. data at 13.5MeV is consistent with DWBA prediction

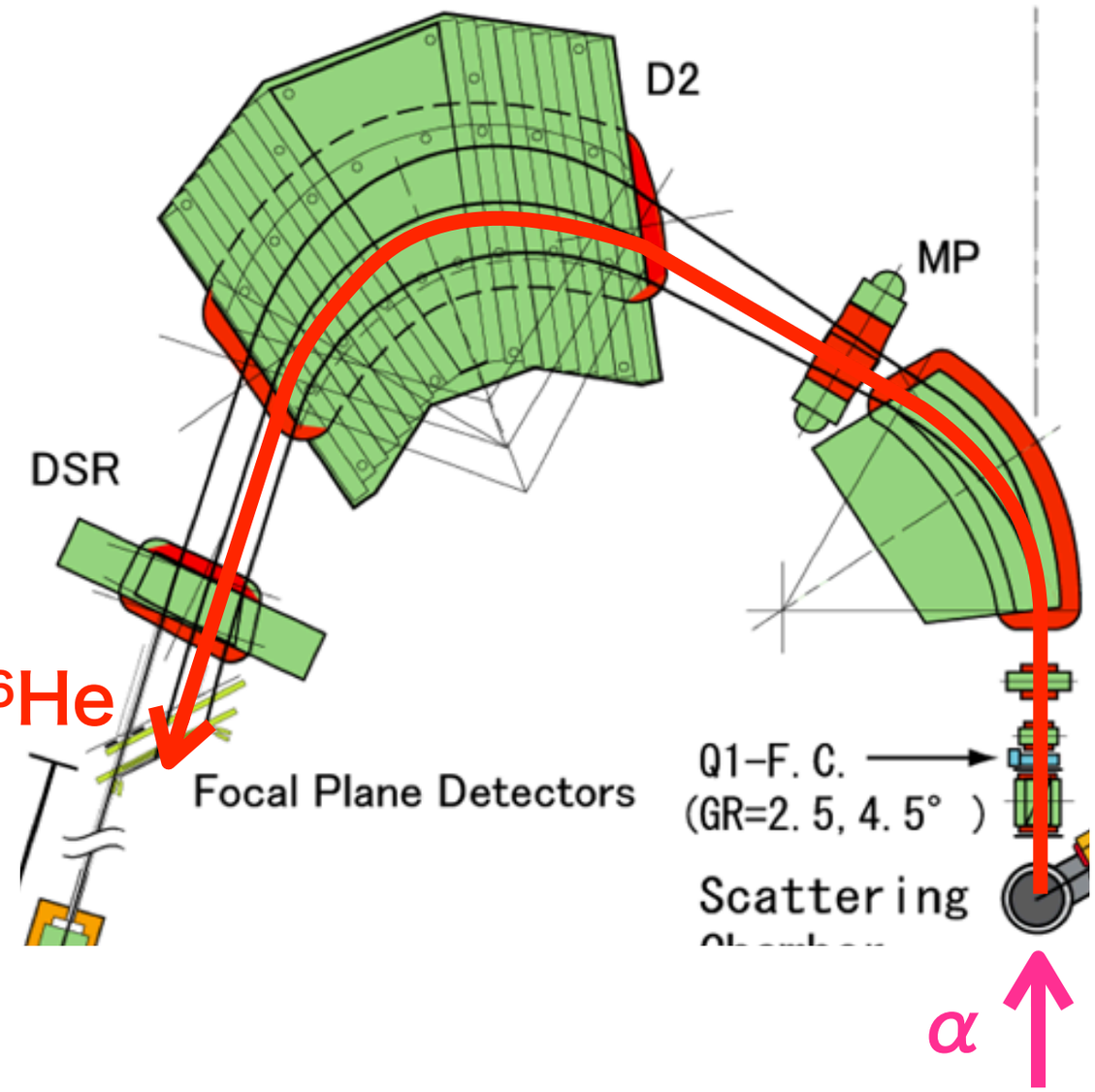


Candidate for high-lying PV ?
Further measurement is needed
(Especially forward-angle data)

Planed experiments at RCNP

- **α beam : 60~120MeV**
- **Sn target : A=112-124**
  - 3~10 mg/cm^2
- **Reaction : (α,^{6}He)**
  - ^{6}He detection with Grand Raiden
    - E_x = 0 — 20 MeV
    - θ = 1 — 10^o
- **Grand Raiden spectrometer serves as a separator from huge BG events (beam, elastic)**
- **BG-free measurement for the forward angular region !!**

Grand Raiden spectrometer



Summary

- High-lying pair vibration is a key
  to understand the mechanism of pair-condensation
- To probe high-lying PV, we devised (α,^{6}He) reaction
- Test experiment @ CYRIC showed
  effectiveness of (α,^{6}He) reaction
  - ^{120}Sn(α,^{6}He)^{118}Sn @ 100MeV
  - Clear peak @ 13MeV in ^{118}Sn
- New experiment using GR spectrometer is planed at RCNP

最後に

- 公募研究開始当初は
  「高励起領域にある対振動モード(巨大対振動)を調べたい」
  という動機のみで、核子対凝縮との絡みは一切考えていませんでした

- 公募研究の中で多くの方々と議論していくうちに
  核子対凝縮への道筋が見えてきました

- この研究が種となり
  核子対凝縮の性質解明に向けた
  PHANESプロジェクト
  (リーダー：大田@RCNP)
  を立ち上げました

感謝申し上げます