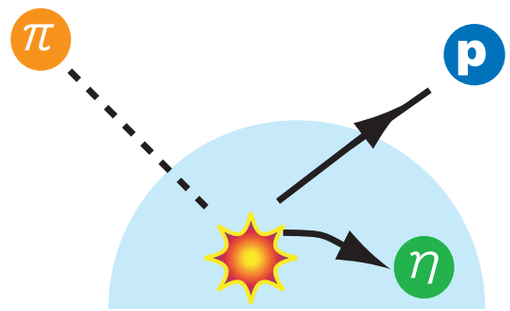
In-medium properties of N(1535) probed by eta-mesic nuclei and chiral symmetry for baryon resonance

D. Jido (YITP, Kyoto)

H. Nagahiro (RCNP, Osaka)

S. Hirenzaki (Nara WU)

E.E. Kolomeitsev (GSI)



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Nuclear Physics at J-PARC - *Pre-symposium of INPC 2007* -
June 1st - 2nd, 2007 at "RICOTTI" in Tokai village

Introduction

η meson - nucleus system

ηN system strongly couples to N(1535)

N(1535): $J^P = 1/2^-$
S-wave coupling

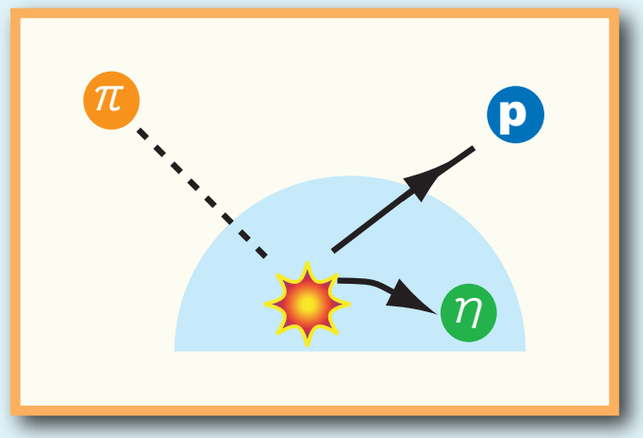
N(1535)-hole contributions important

cf. π-nucleus system: Δ-hole

can observe in-medium effect on N(1535) as well as on η

Formation reaction

$(\mathrm{d},{}^3\mathrm{He}),\ (\gamma,p),\ (\pi,p),\ \cdots$



missing mass spectra

recoilless condition (zero momentum transfer)

to stop eta in nucleus

Models of in-medium N(1535)

DeTar, Kunihiro PRD39, 2805 (89)
Jido, Nemoto, Oka, Hosaka NPA671, 471 (00)
Jido, Oka, Hosaka PTP106, 873 (01)

N(1535): Possible candidate of chiral partner of N

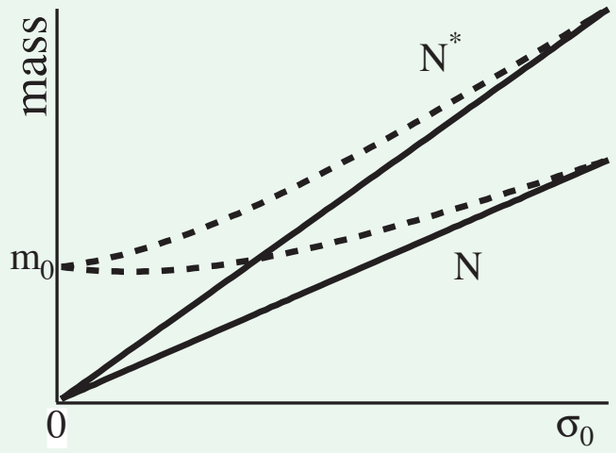
Chiral Partner Chiral doublet model

N and N* : **chiral multiplet** of $SU(2)_L \otimes SU(2)_R$

at ChRP, N and N* degenerate, ChSB splits the masses

Assuming partial restoration of ChS in nuclear medium

reduction of mass difference as density increases



$$m_N^*(\rho) - m_{N^*}^*(\rho) = A\langle\sigma\rangle_\rho = (1 - C\frac{\rho}{\rho_0})(m_N - m_{N^*})$$

strength of chiral restoration at the saturation density ρ_0

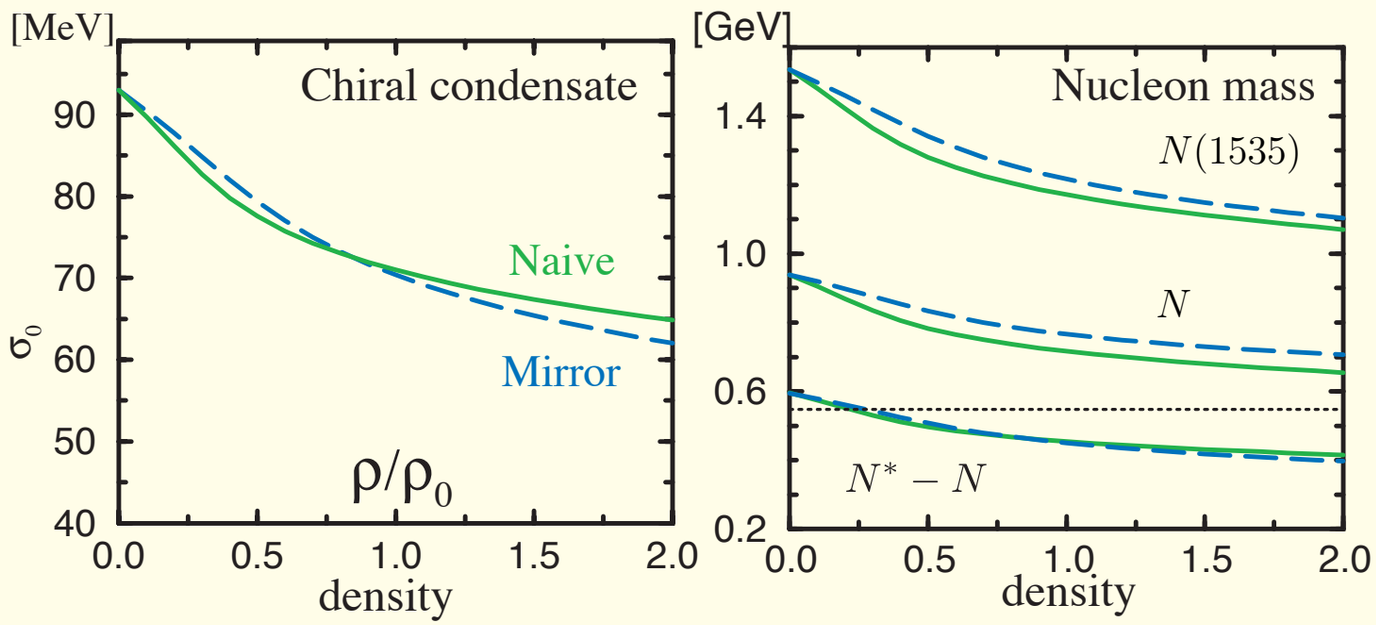
$C = 0.1 \sim 0.3$ πN σ term

Chiral doublet model

chiral condensate
nucleon masses
in nuclear matter

relativistic Hartree approx.

Kim, Jido, Oka
NPA640,77 (1998)



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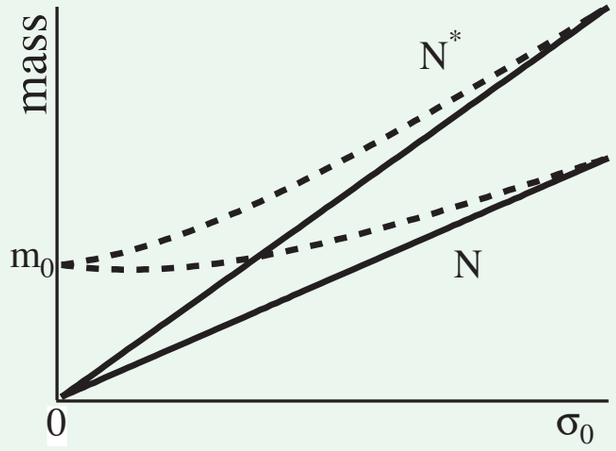

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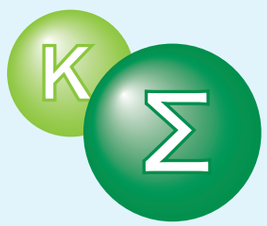
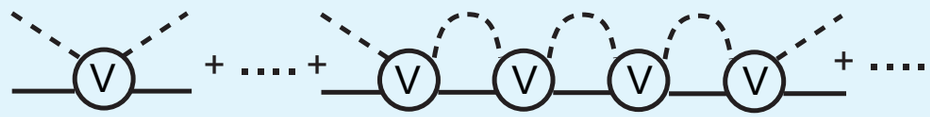
Meson-Baryon Bound State Chiral unitary model

N* is introduced as a **resonance** generated dynamically in meson-baryon scattering

essentially
quasi bound state of KΣ





N*: insensitive to the medium effect !!

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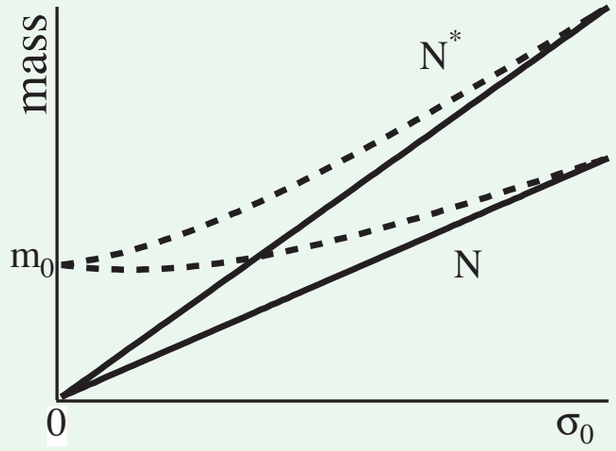

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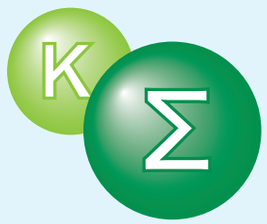
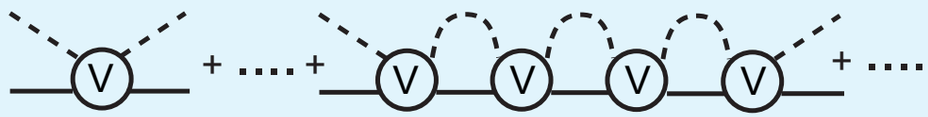




N*: insensitive to the medium effect !!

Kaiser, Siegel, Weise, PLB362, 23 (95)
Waas, Weise, NPA625, 287 (97)
Garcia-Recio, Nieves, Inoue, Oset, PLB550, 47 (02)
Inoue, Oset, NPA710, 354 (02)

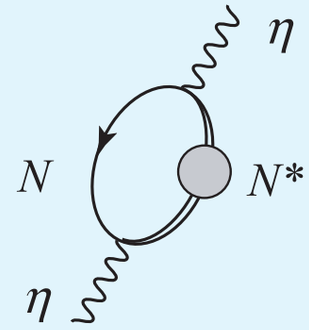
Jido, Nagahiro, Hirenzaki, PRC66, 045202 ('02)

Optical potential of η in nucleus

Assumption

1) N* dominance: Consider only N*-hole excitation.
2) s-wave coupling for η NN*
3) η at rest in nucleus due to the recoilless condition

N*-hole excitation



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$$V_\eta(\omega) = \frac{g_\eta^2}{2\mu}\frac{\rho(r)}{w + m_N^*(\rho) - m_{N^*}^*(\rho) + i\Gamma_{N^*}(\omega;\rho)/2}$$

g_η	ηNN* coupling
μ	η-nucleus reduced mass
w	η energy

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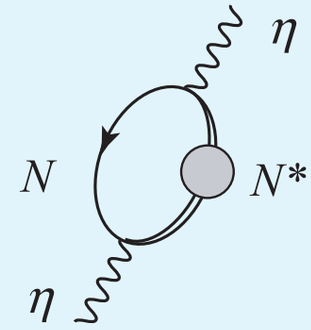

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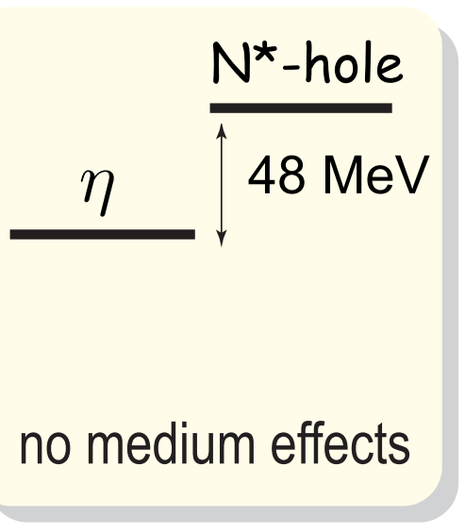

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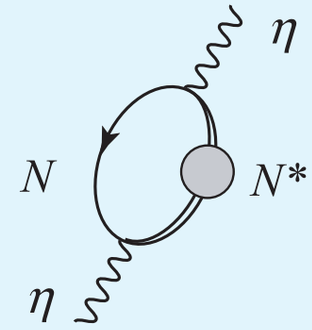

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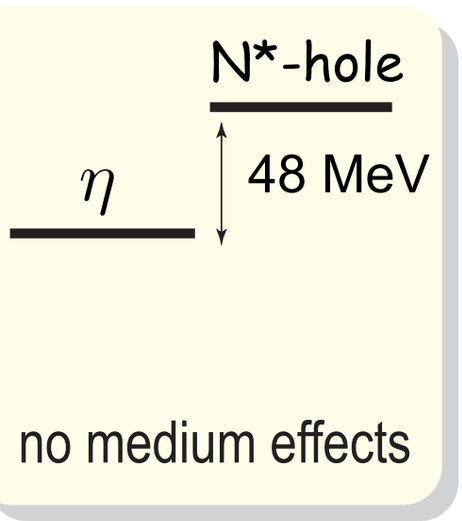
Real part of optical potential depends on eta energy and mass difference of N and N*.

$\omega + m_N^* - m_{N^*}^* > 0$ attraction

$\omega + m_N^* - m_{N^*}^* < 0$ repulsion

Density dependence

Energy dependence



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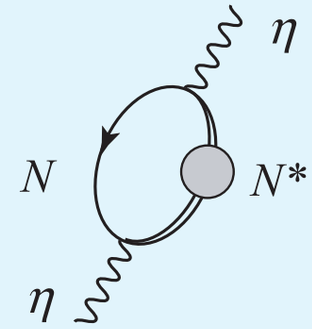

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Real part of optical potential depends on eta energy and mass difference of N and N*.

We have seen reduction of N-N* mass difference in nuclear medium in chiral doublet model.

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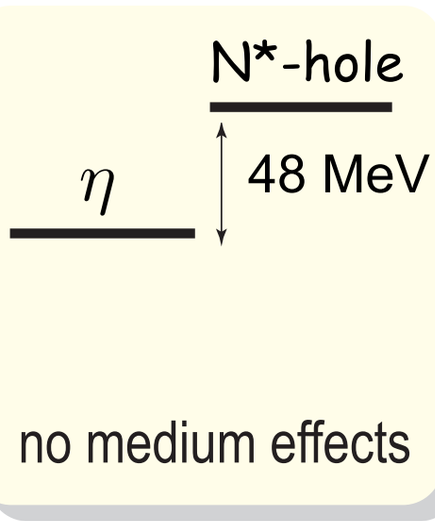

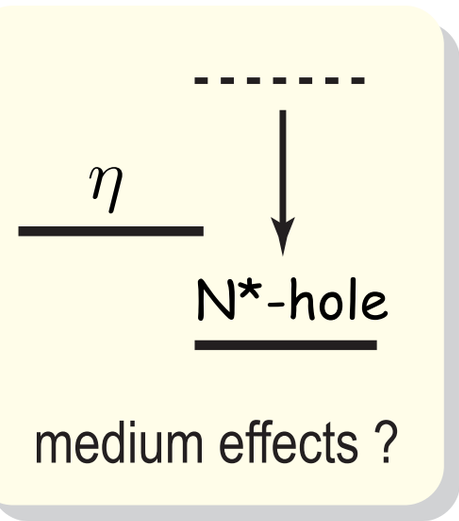

level crossing

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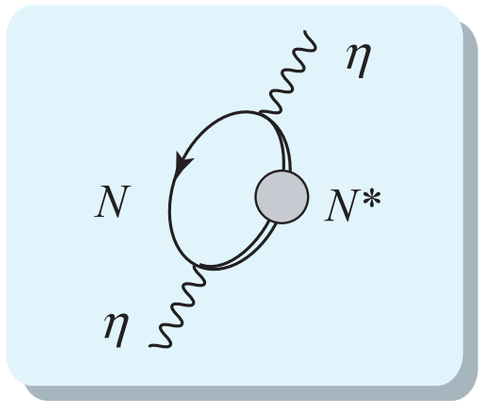
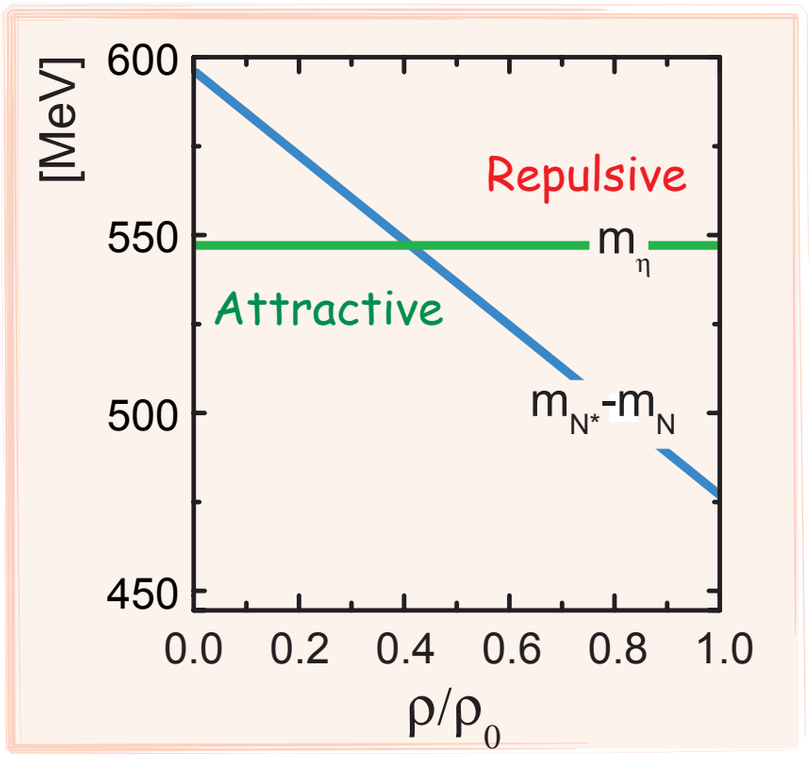
Optical potential of η in nucleus

Density dependence fixing energy at $\omega = m_\eta$

N(1535)* dominance

N*-hole excitation





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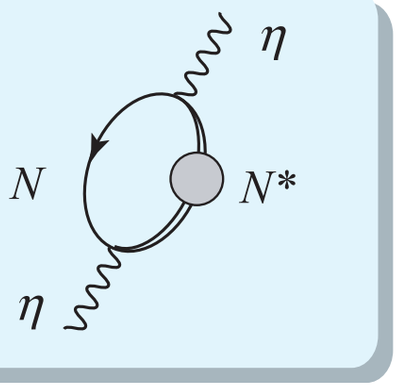
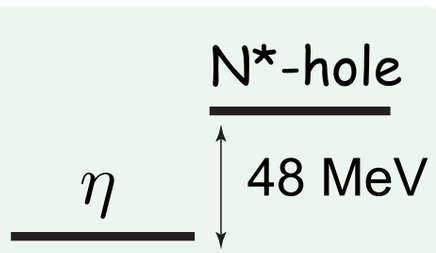
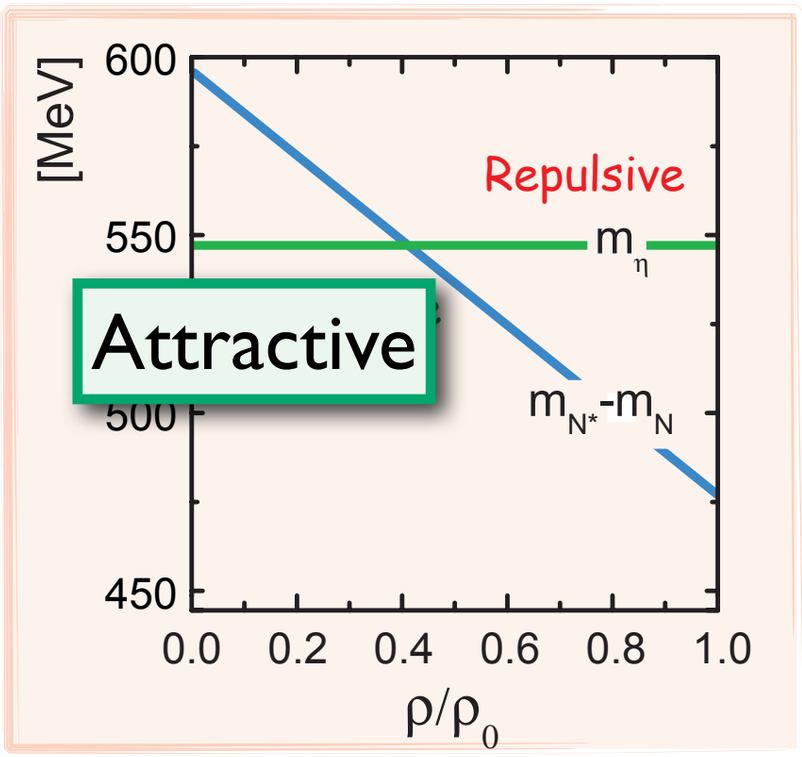


- no strong medium modification for the masses of N and N*

Attractive





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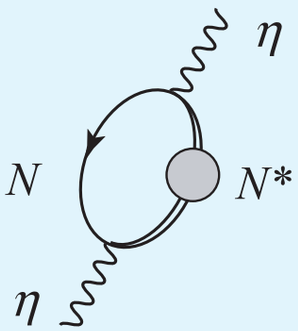

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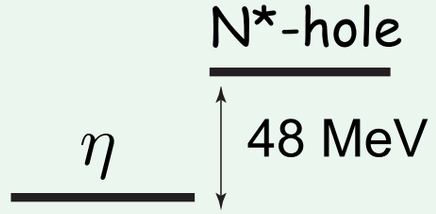
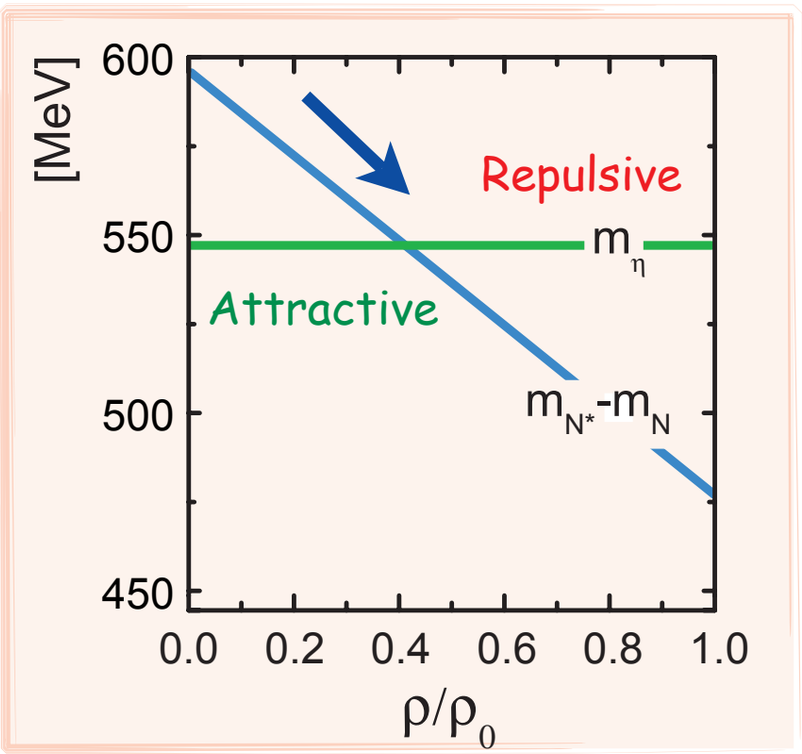


Reduction of mass difference of N and N*



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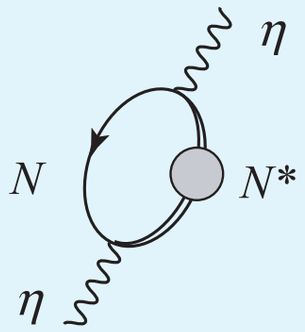

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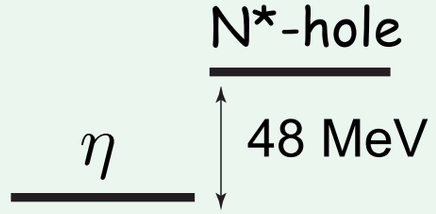
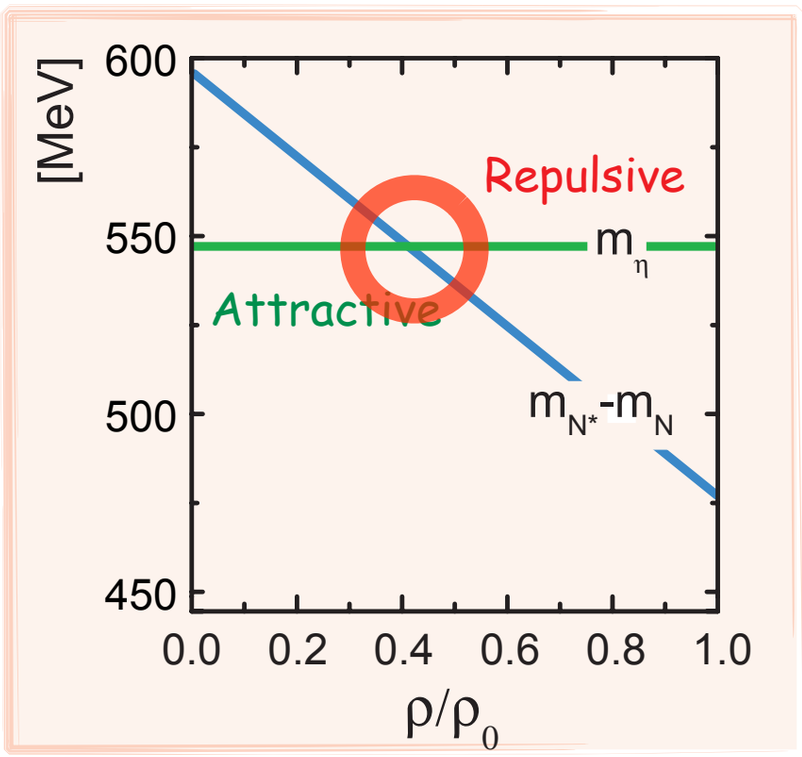


Reduction of mass difference of N and N*

Level crossing between eta and N*-hole modes



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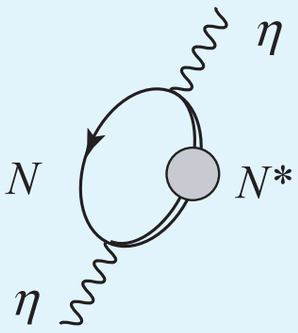

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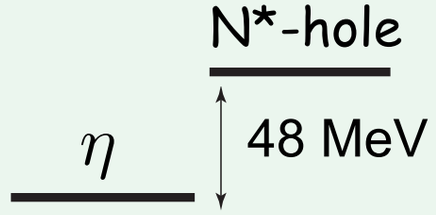

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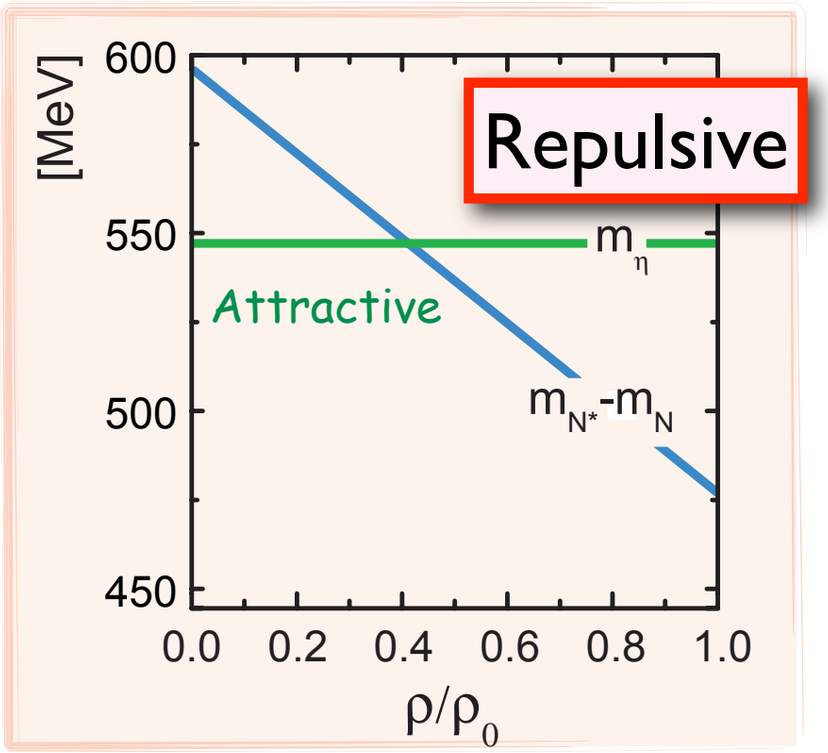
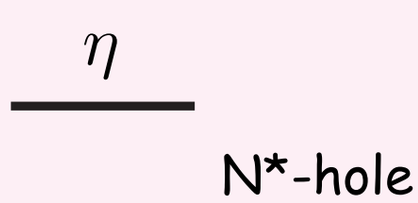


Level crossing between eta and N*-hole modes

- sufficient reduction of the mass difference of N and N*

Repulsive



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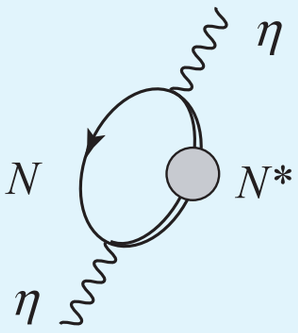

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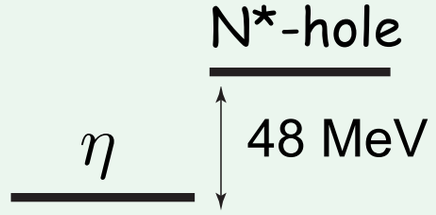

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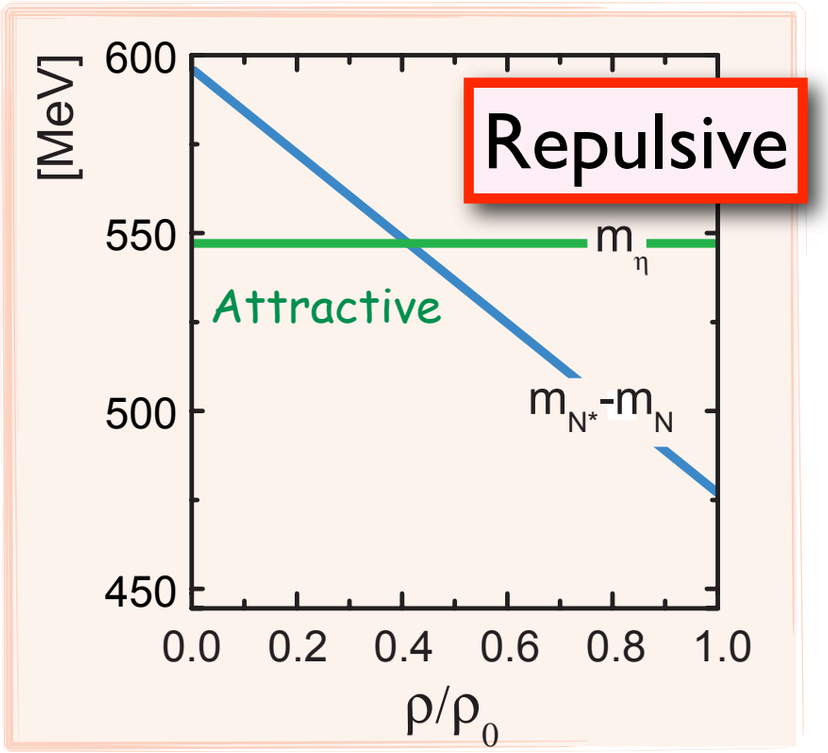
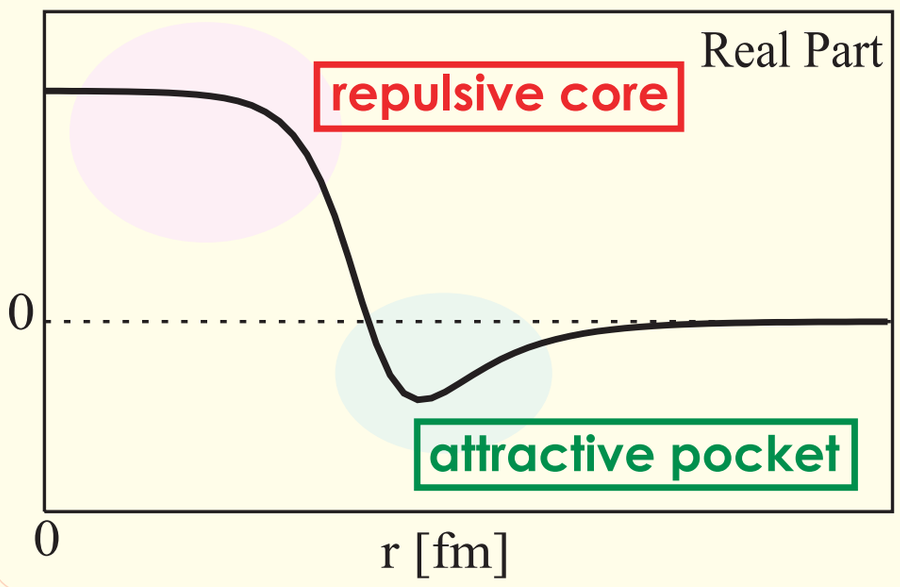


Level crossing between eta and N*-hole modes

Optical potential $\omega = m_\eta$



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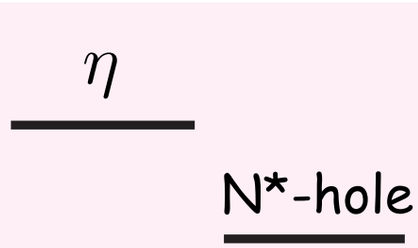


Jido, Kolomeitsev, Nagahiro, Hirenzaki, in preparation

Green function of in-medium eta meson

Energy dependence

potential strongly depends on energy

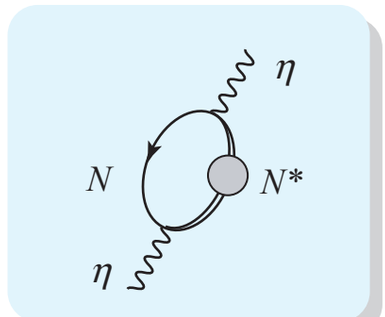
→ bound states calculated in self-consistent way

Green function

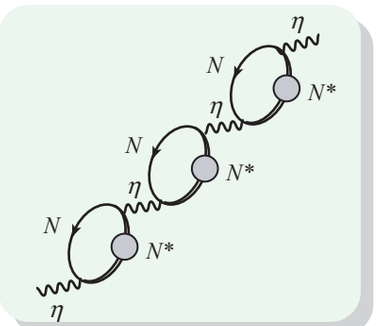
$$G_\eta(\omega) = \frac{1}{\omega - m_\eta - V_\eta(\omega)}$$

propagation of modes as poles

pole position: in-medium “mass”



Self-energy



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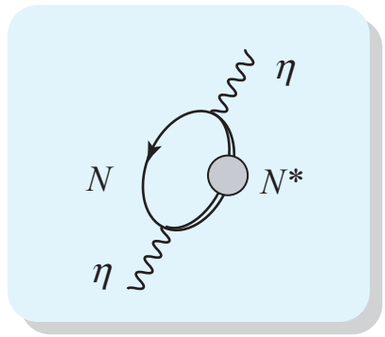
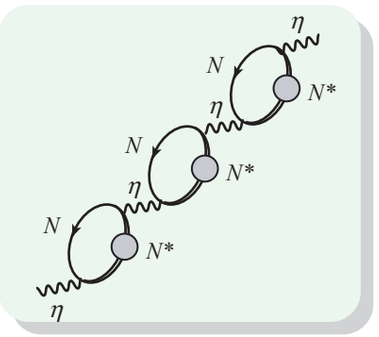


Self-energy



Green function

Two modes of propagation

Eta meson mode

N*–hole mode

couple in nuclear medium

Jido, Kolomeitsev, Nagahiro, Hirenzaki, in preparation

Green function of in-medium eta meson

Energy dependence

potential strongly depends on energy

→ bound states calculated in self-consistent way

Green function

$$G_\eta(\omega) = \frac{1}{\omega - m_\eta - V_\eta(\omega)}$$

propagation of modes as poles

pole position: in-medium "mass"

Two modes of propagation

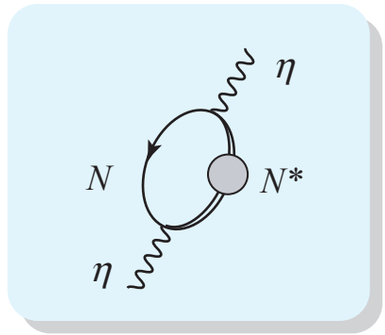
Eta meson mode

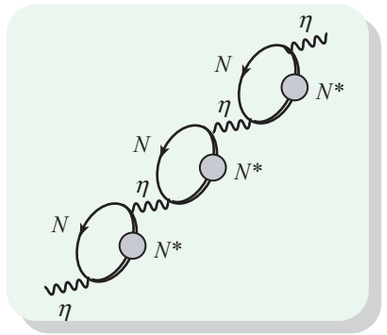
N*–hole mode

couple in nuclear medium

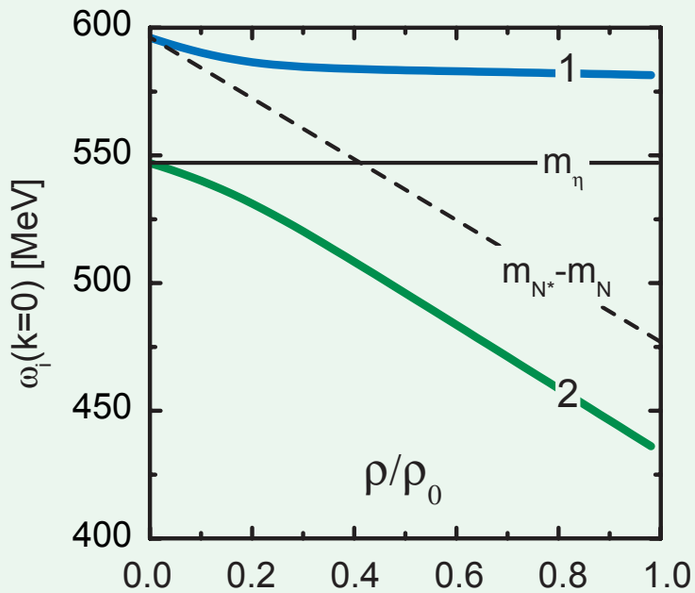
change places

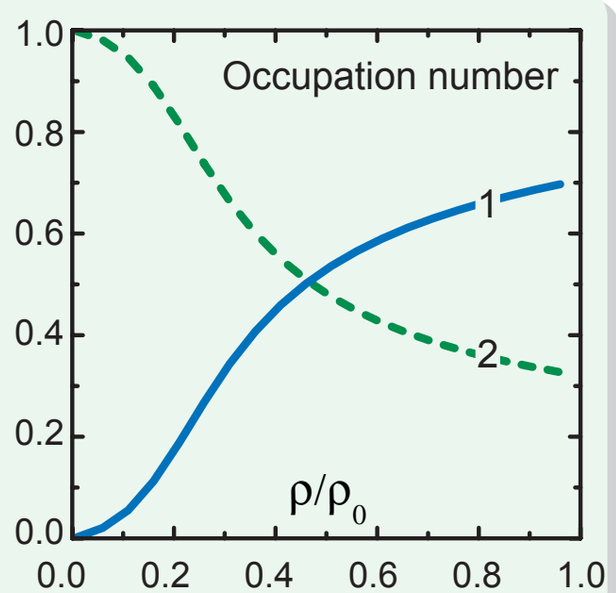
if level crossing takes place





Self-energy Green function





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Jido, Kolomeitsev, Nagahiro, Hirenzaki, in preparation

Spectral function of in-medium eta meson

Energy dependence

Infinite matter calc.

Green function

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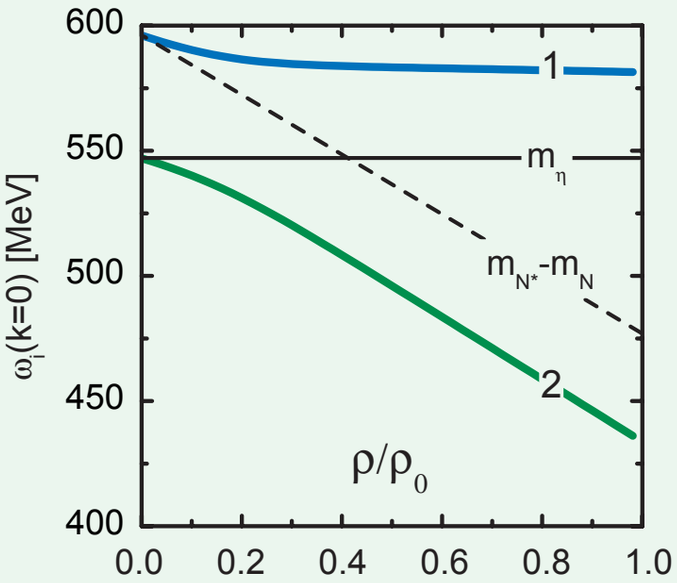
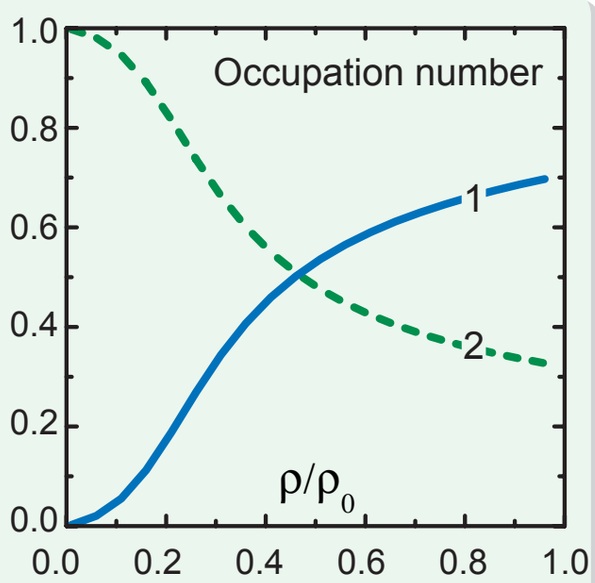
Optical potential of η in nucleus

$$V_\eta(\omega) = \frac{g_\eta^2}{2\mu}\frac{\rho(r)}{w + m_N^*(\rho) - m_{N^*}^*(\rho) + i\Gamma_{N^*}(\omega;\rho)/2}$$





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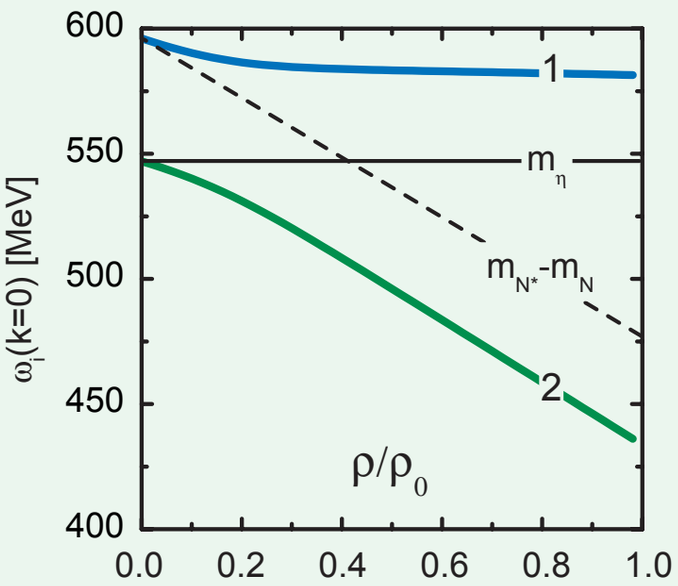

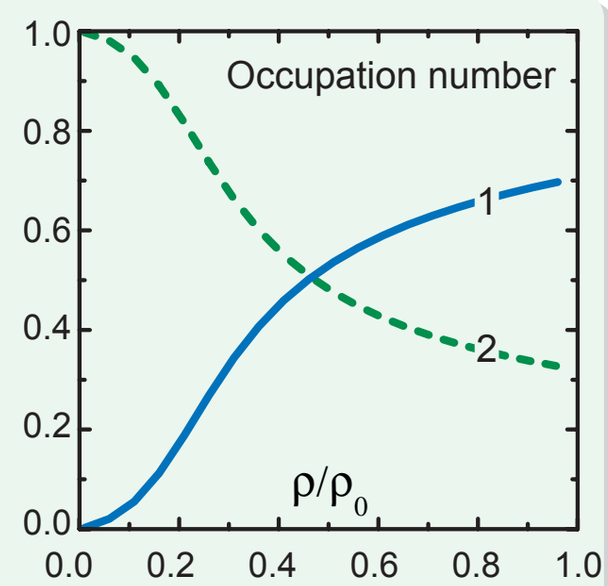

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Spectral function

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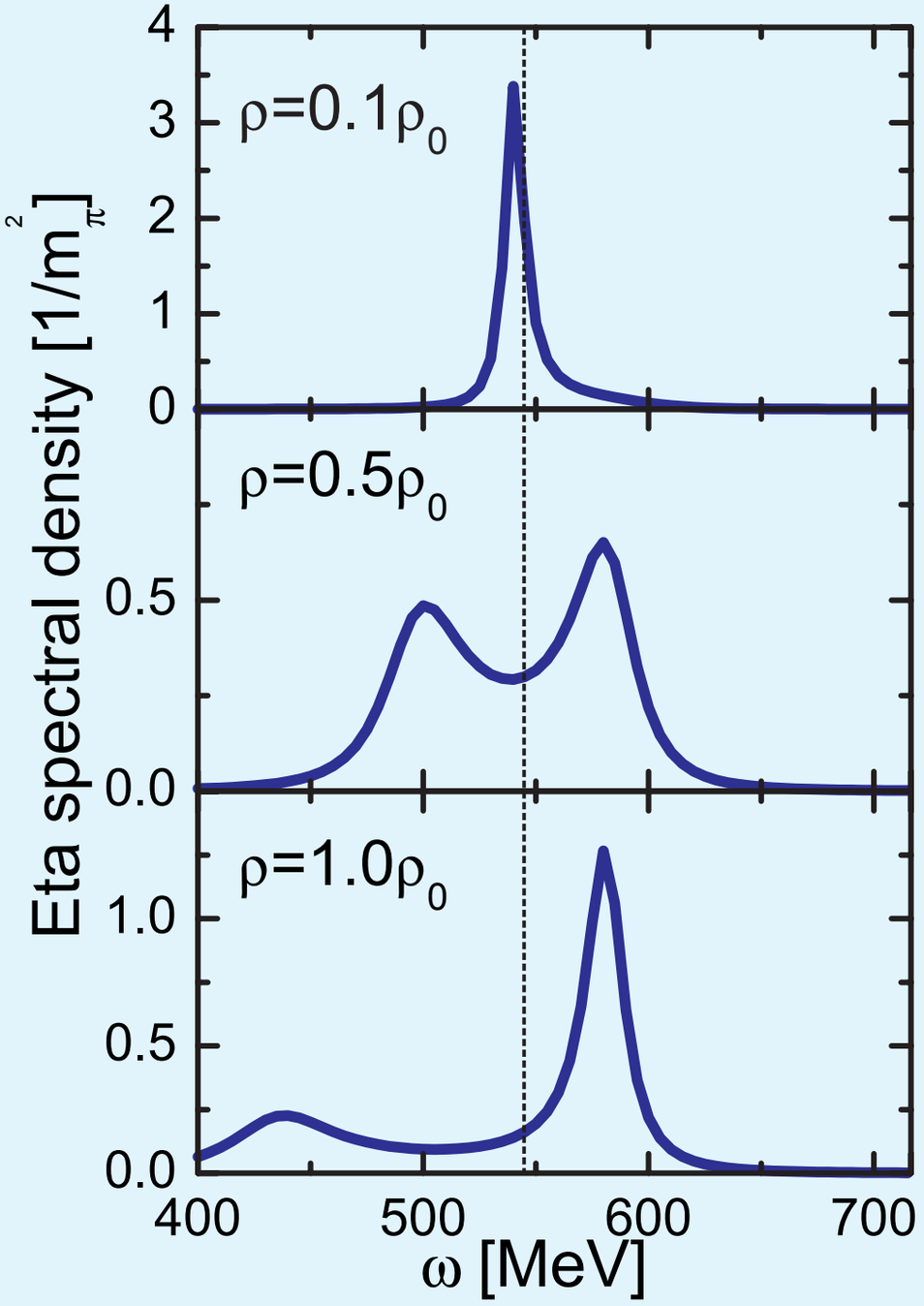

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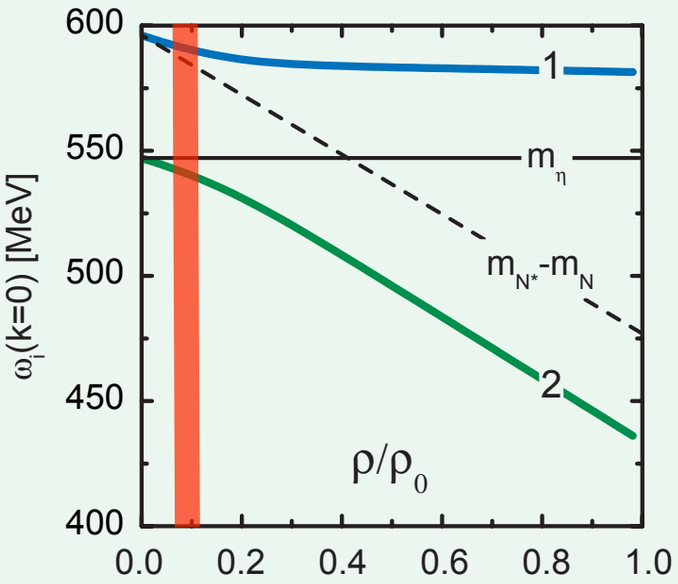

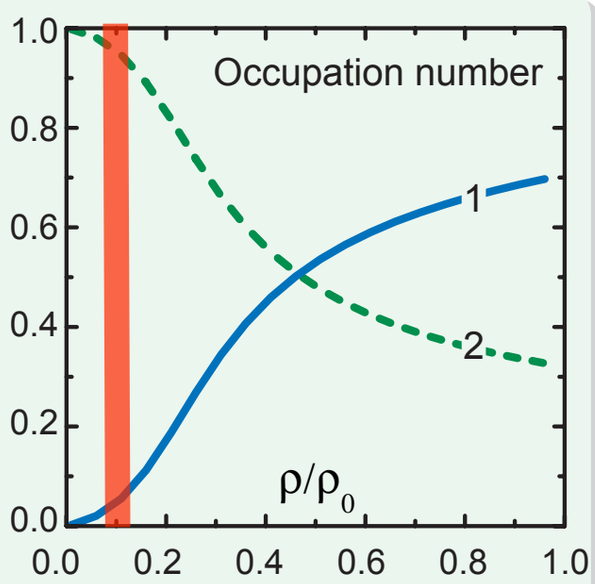

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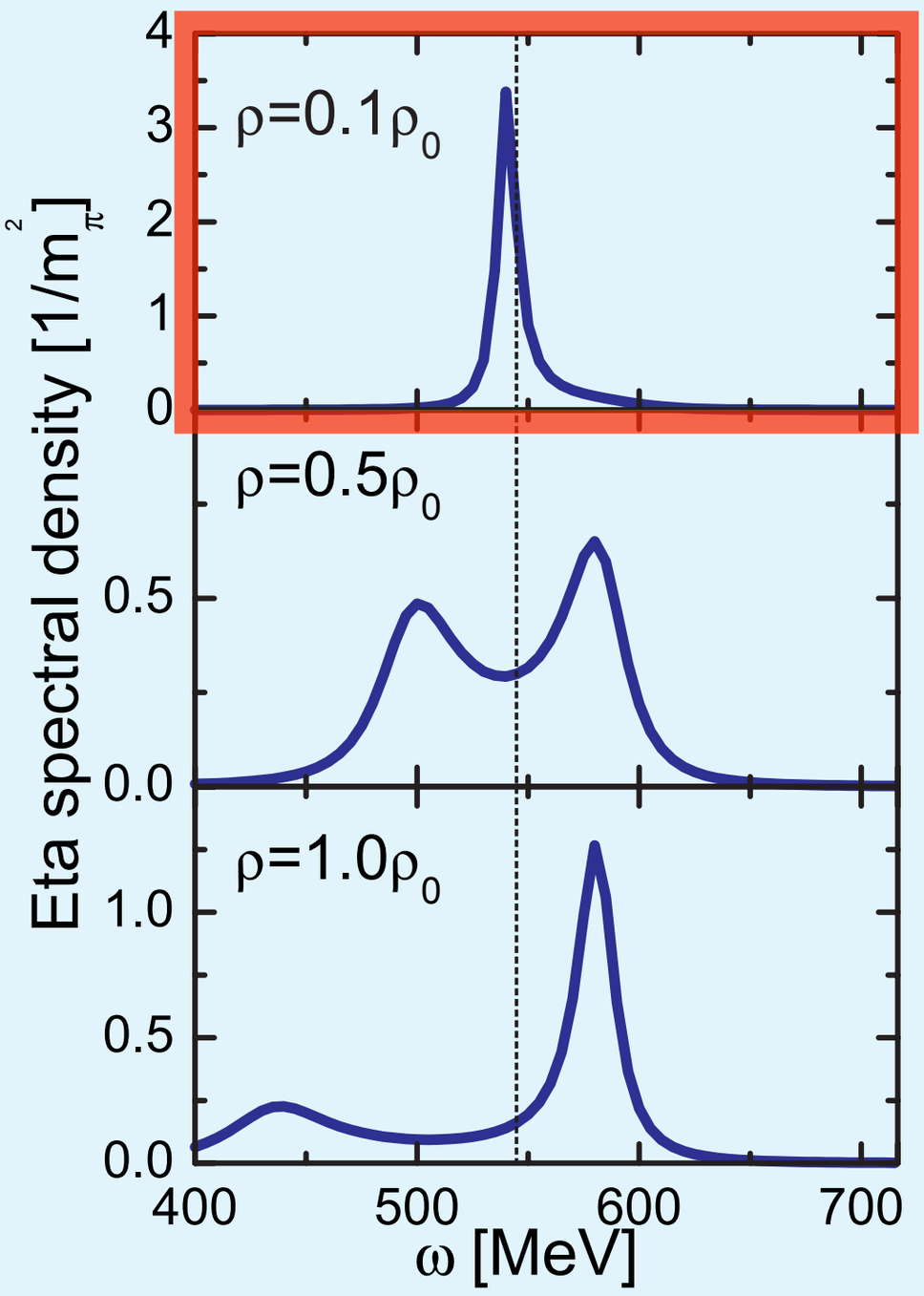

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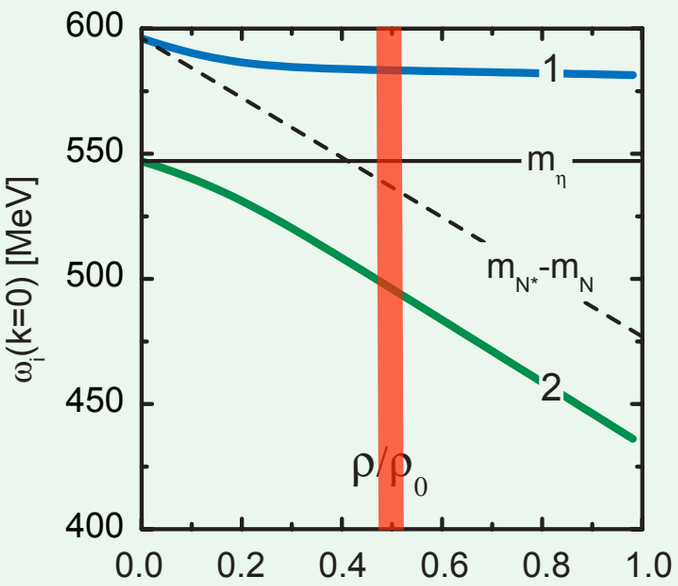

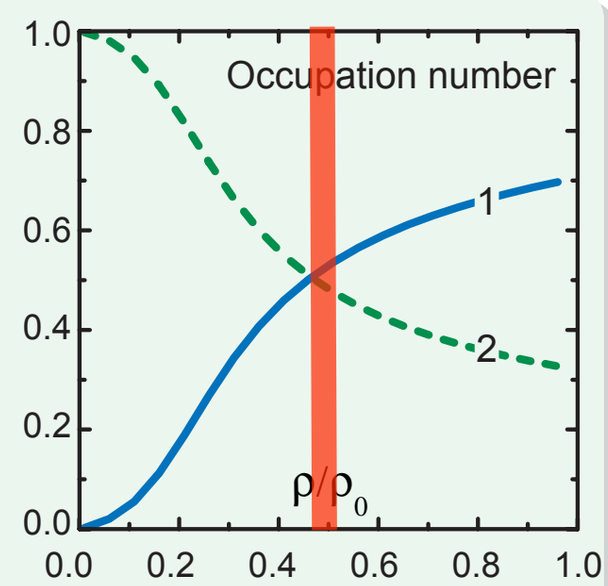

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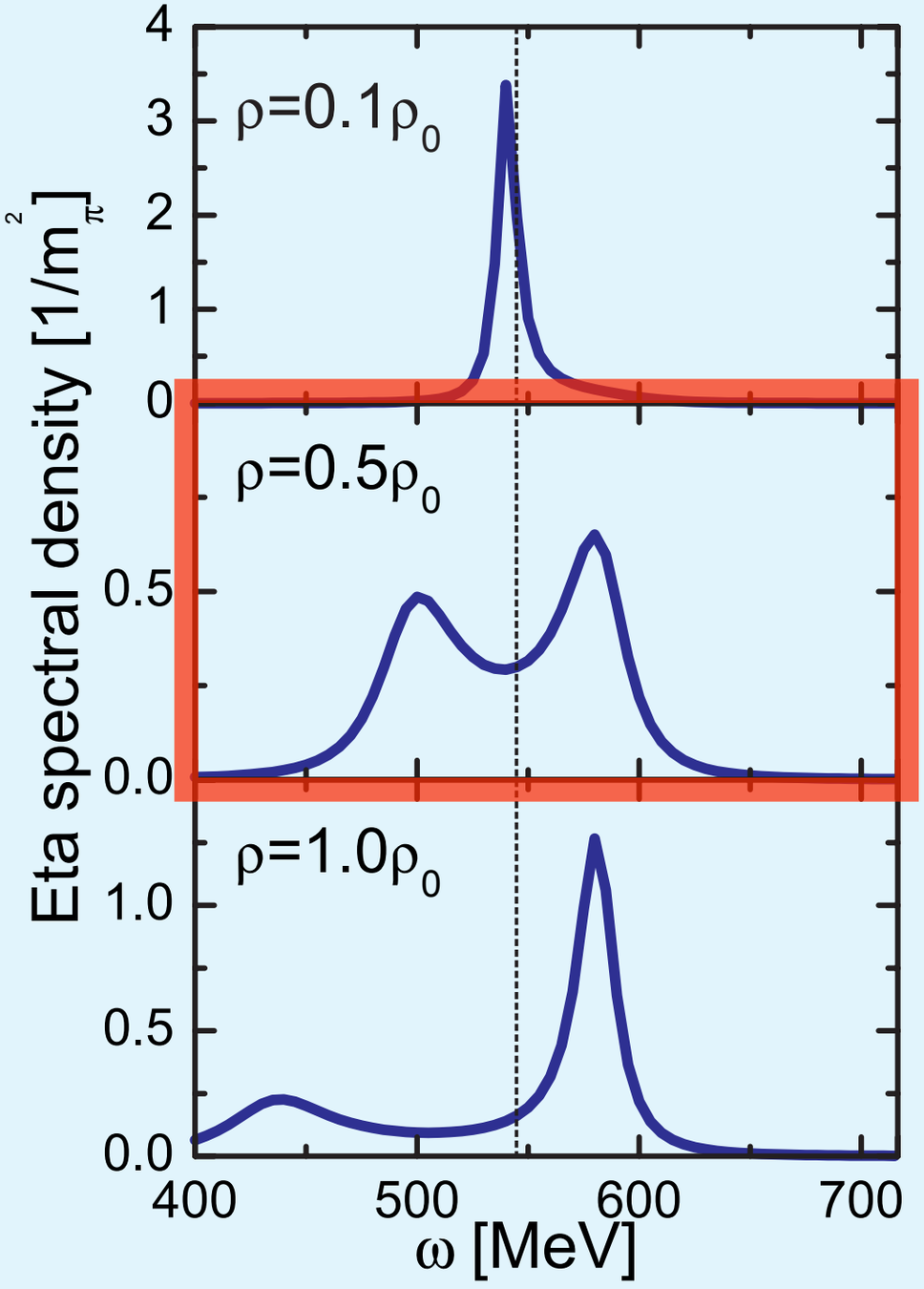

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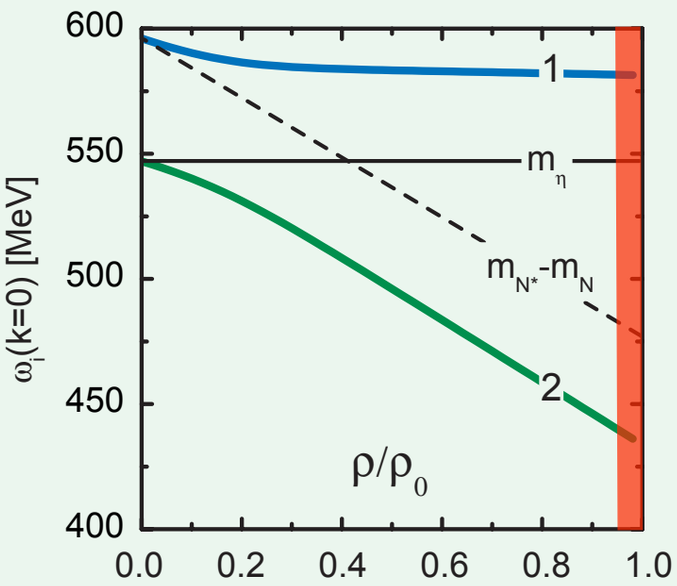

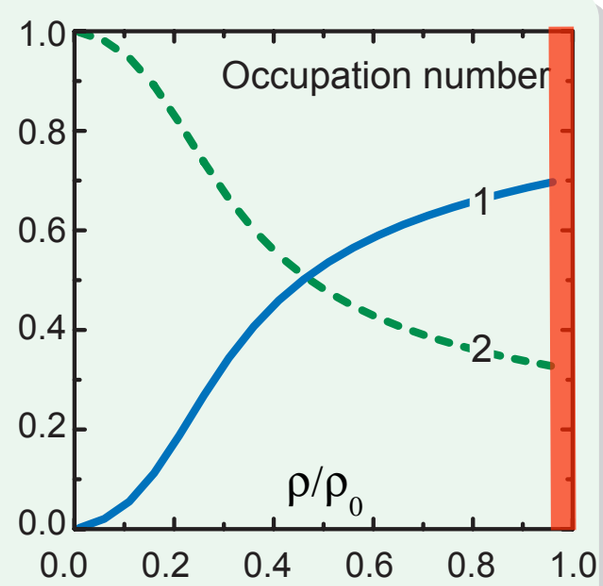

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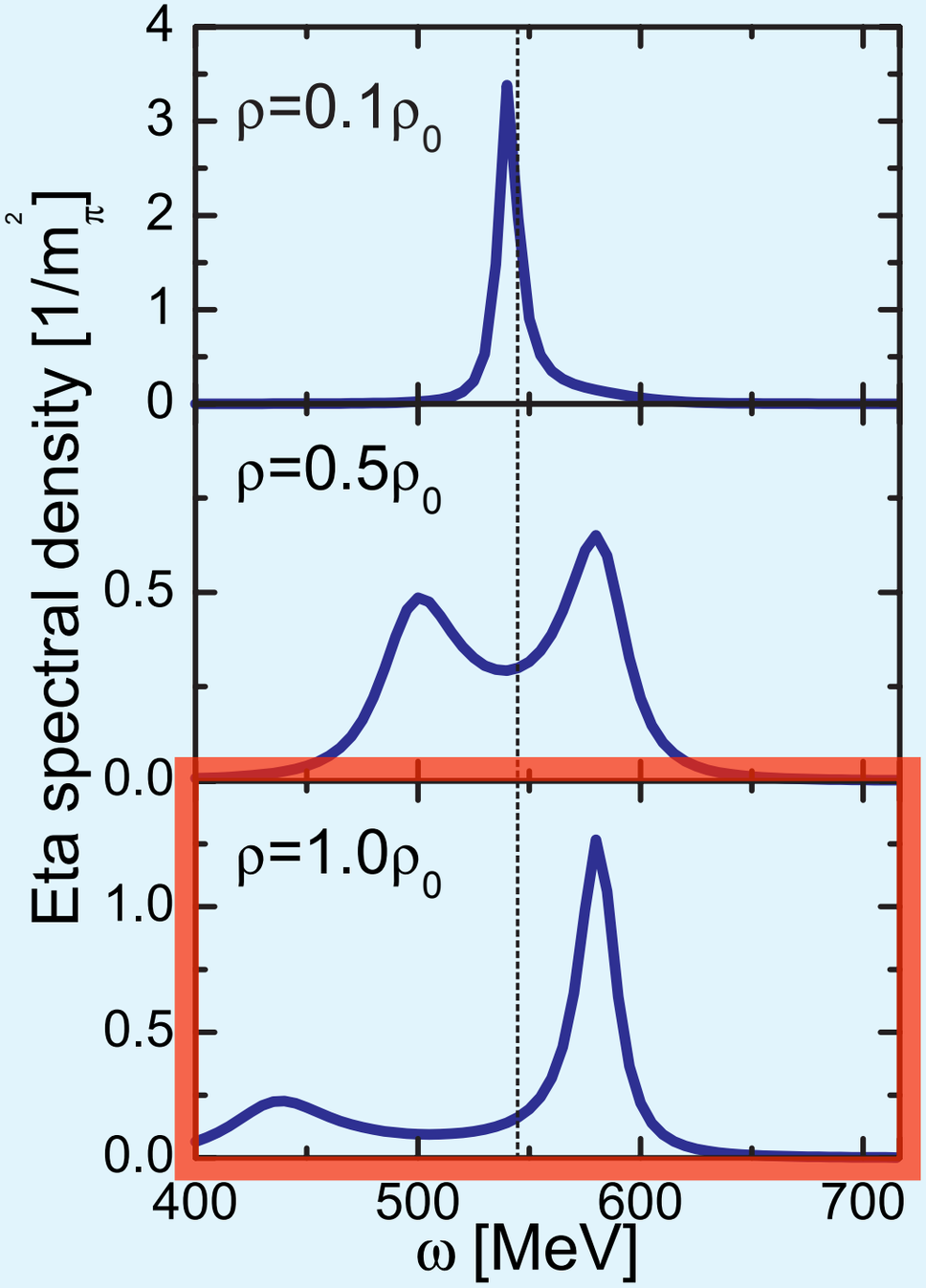
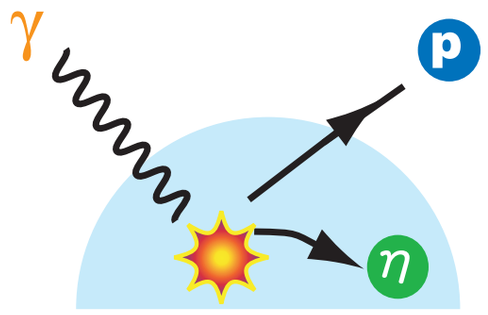


Eta mesic nuclei



consider (γ,p) reaction

missing mass spectra
of emitted proton

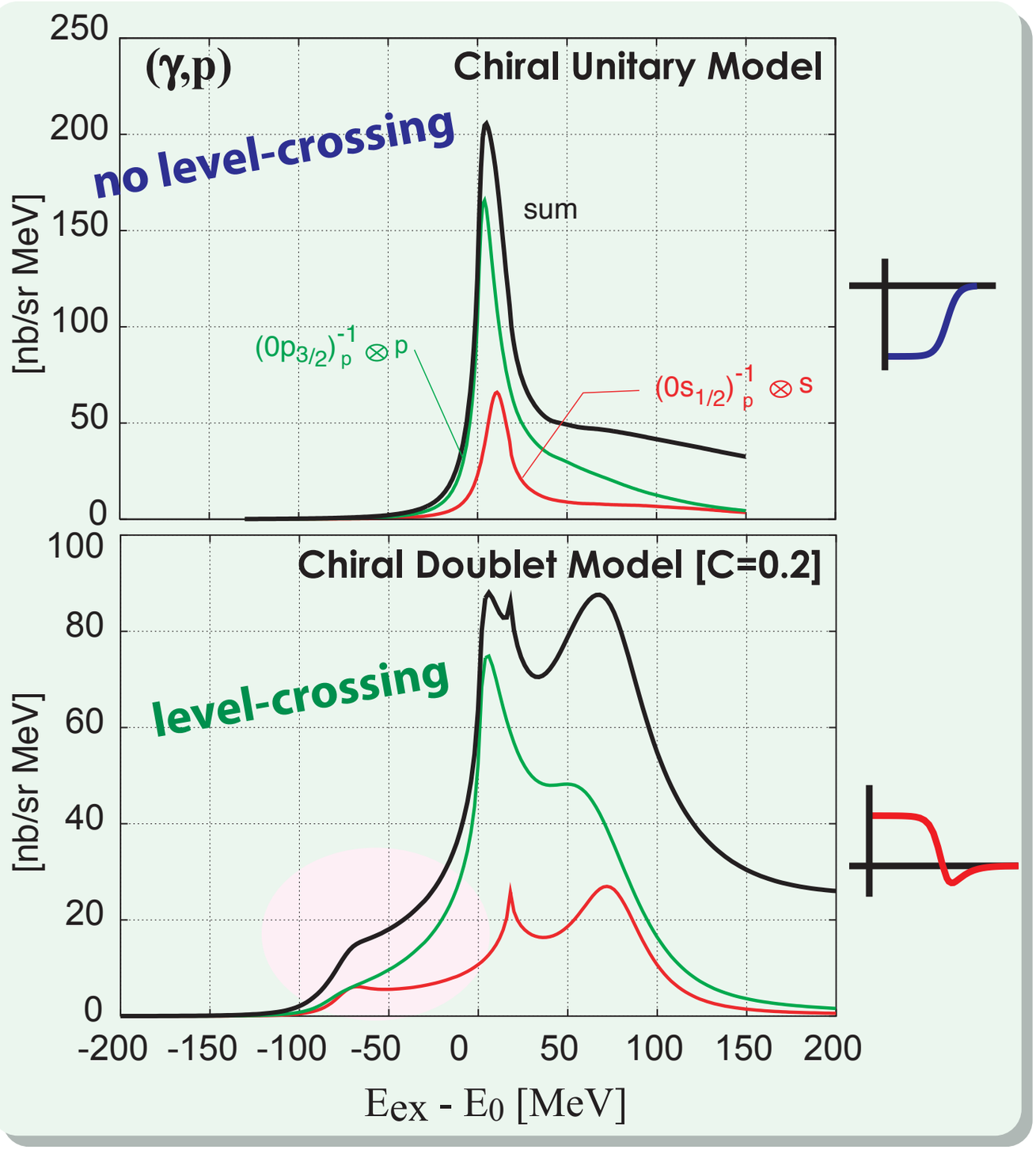
^{12}C target

in recoilless condition
(no momentum transfer)

Green function method
(Morimatsu-Yazaki)

Nagahiro, Jido, Hirenzaki, PRC68, 035805 (03); NPA761, 92 (05)
Jido, Kolomeitsev, Nagahiro, Hirenzaki, in preparation

Spectra of $^{12}C(\gamma,p)^{11}B \otimes \eta$



details and pion induced case → Nagahiro's talk

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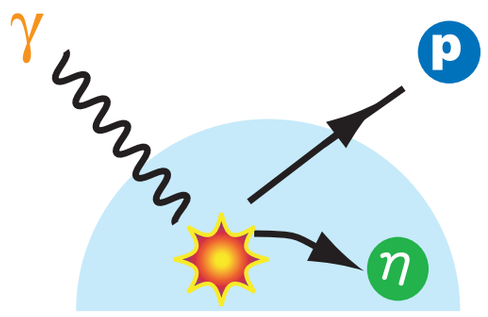

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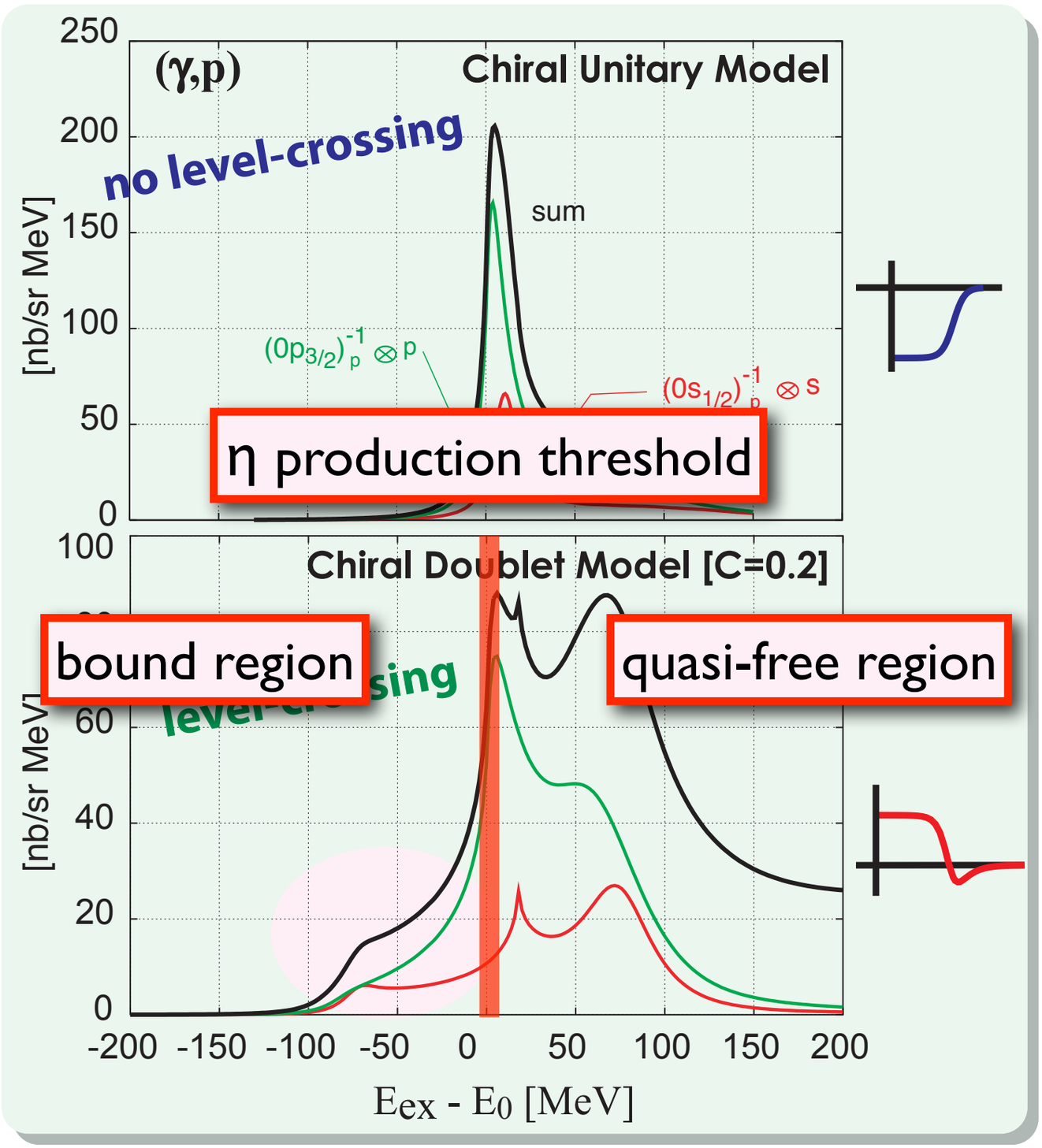

details and pion induced case → Nagahiro's talk

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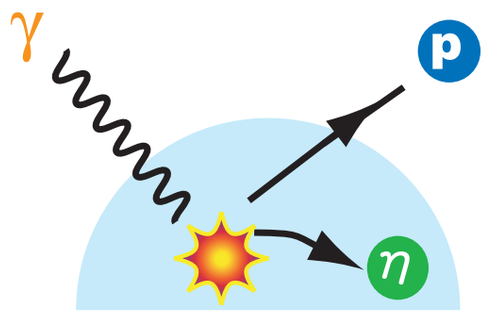

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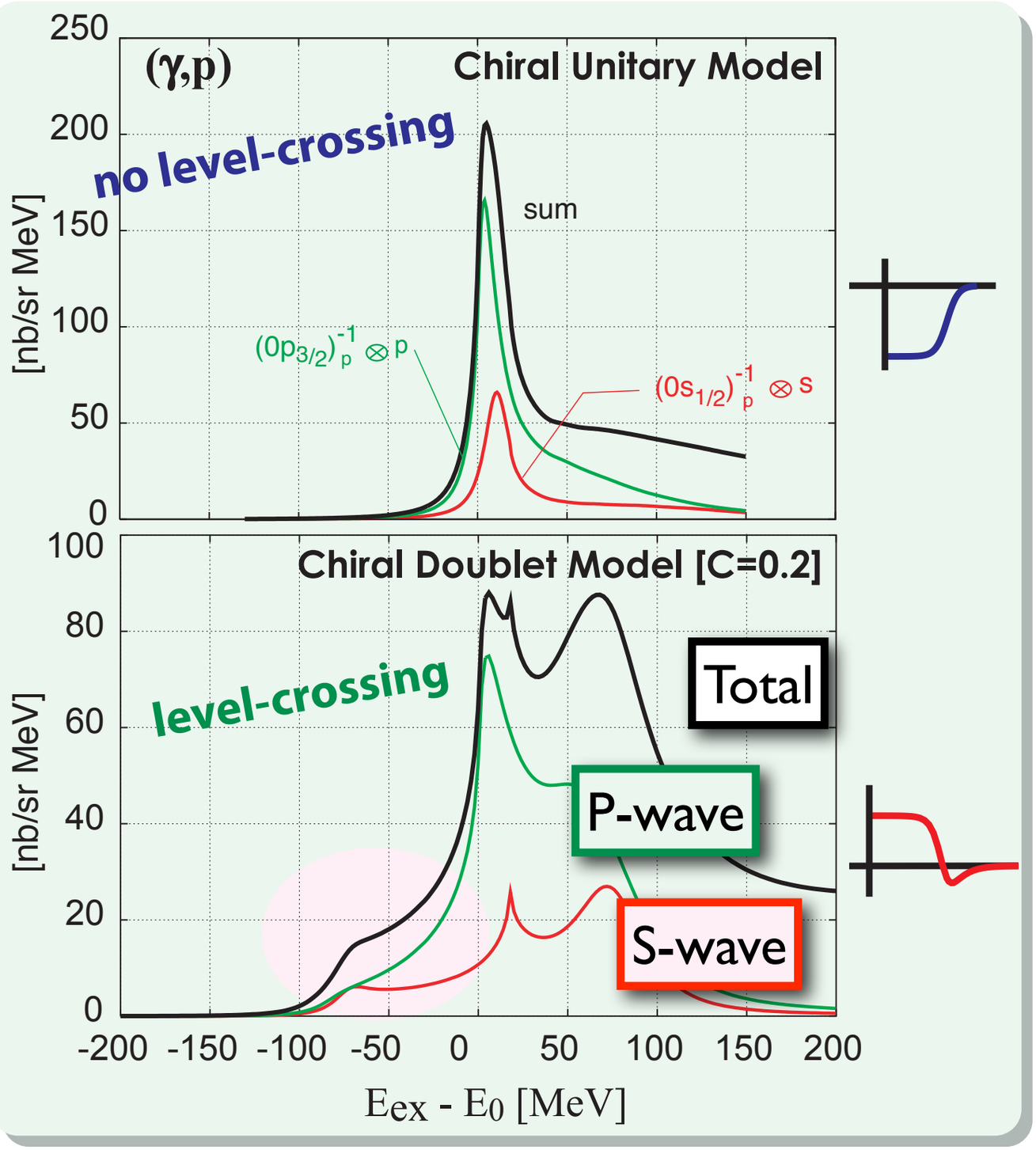

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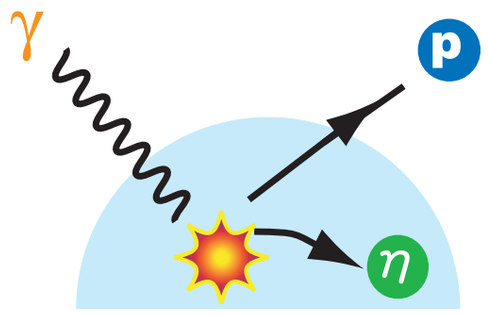

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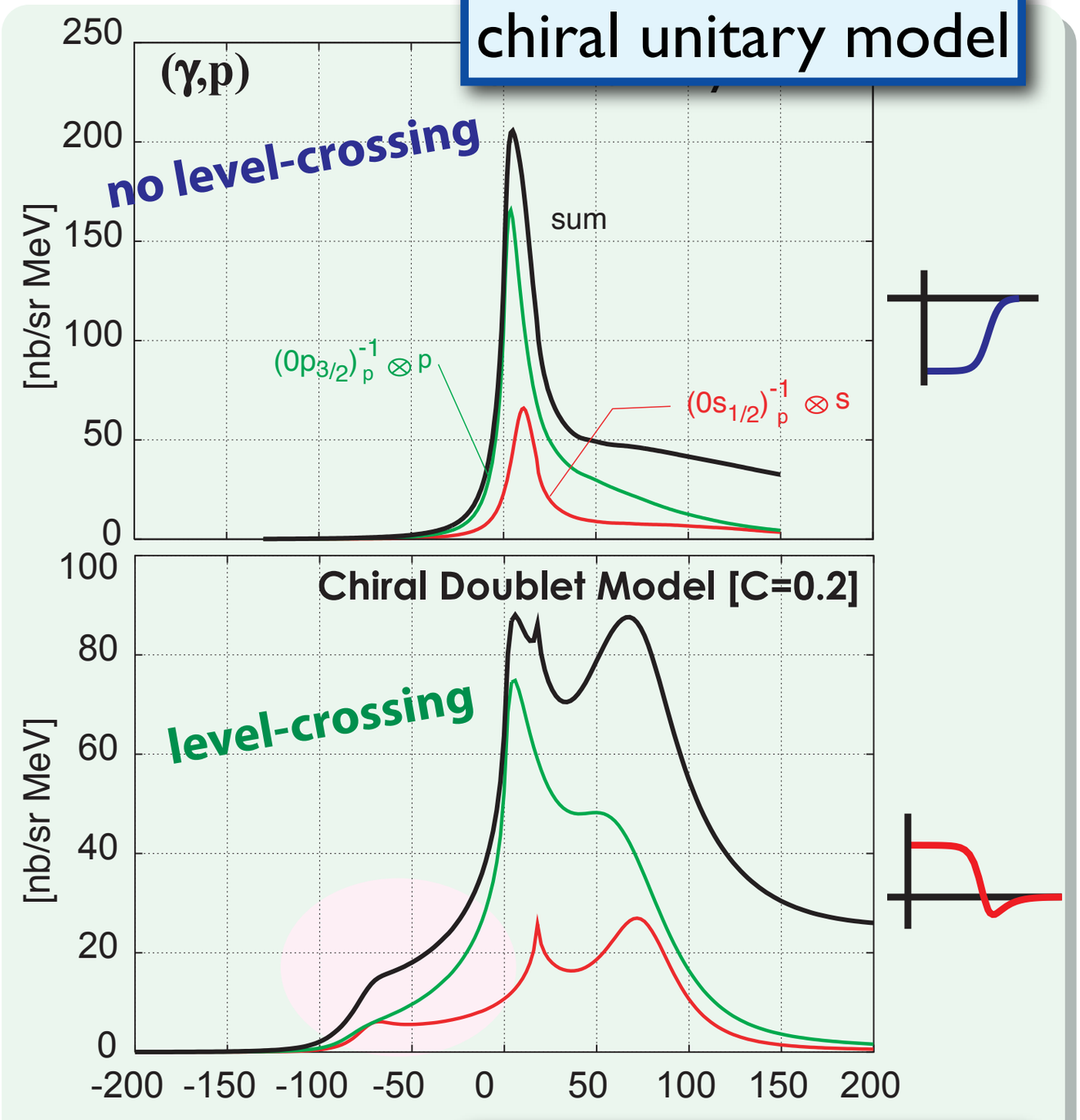
chiral unitary model



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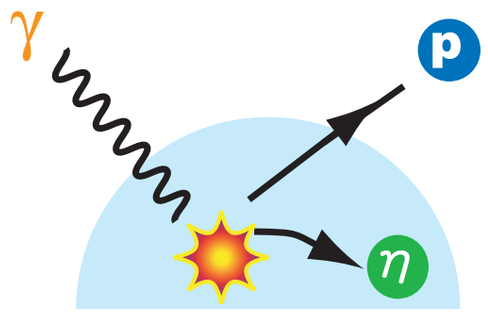

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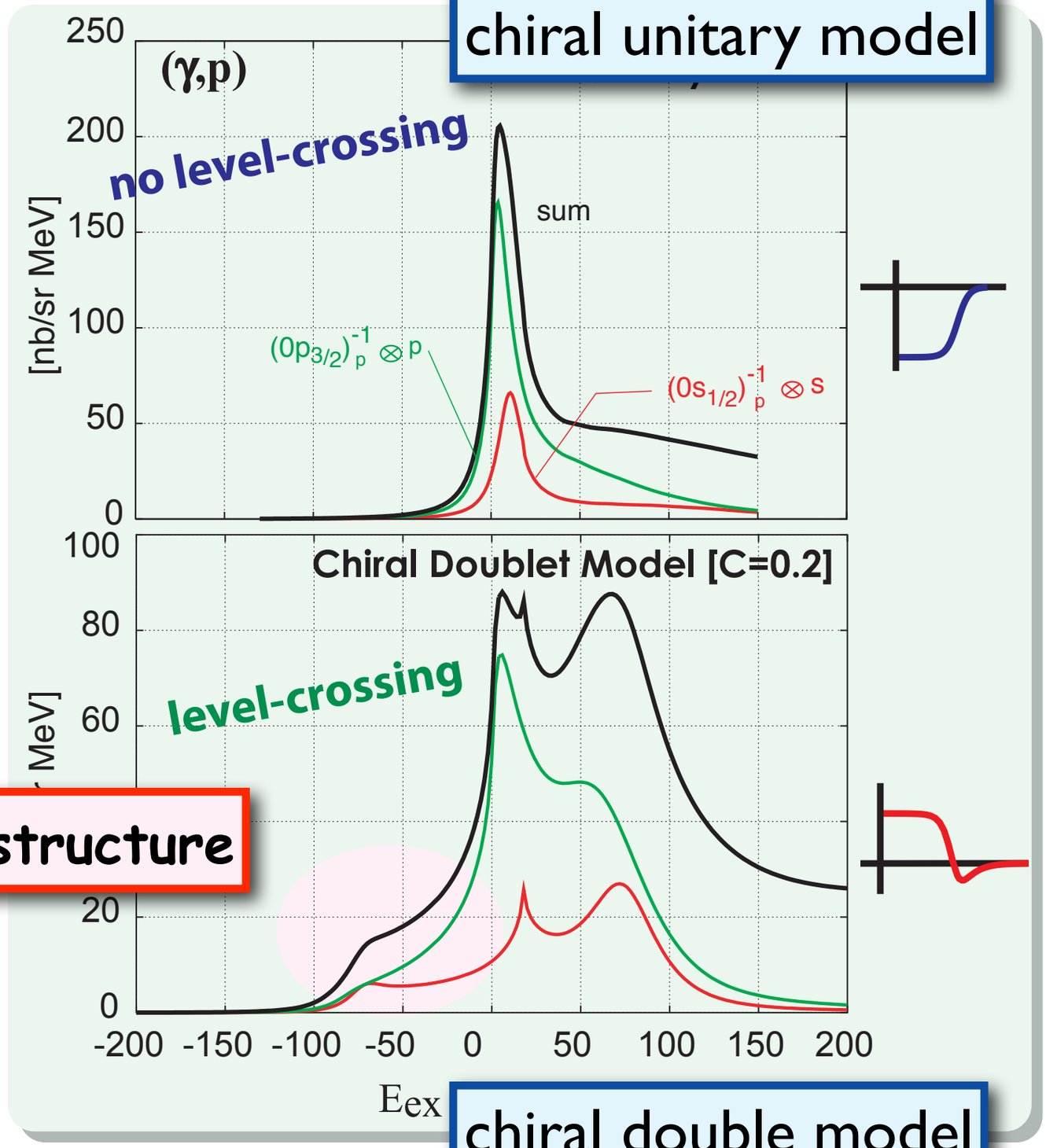

rich structure

chiral double model

details and pion induced case → Nagahiro's talk

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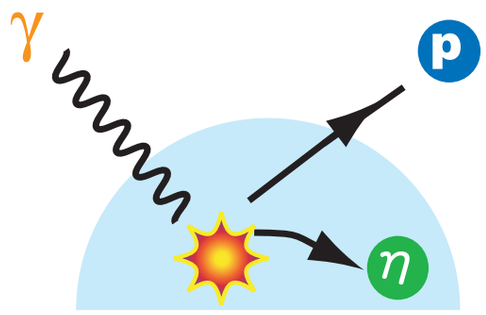

missing mass spectra

emitted proton

photon induced reaction

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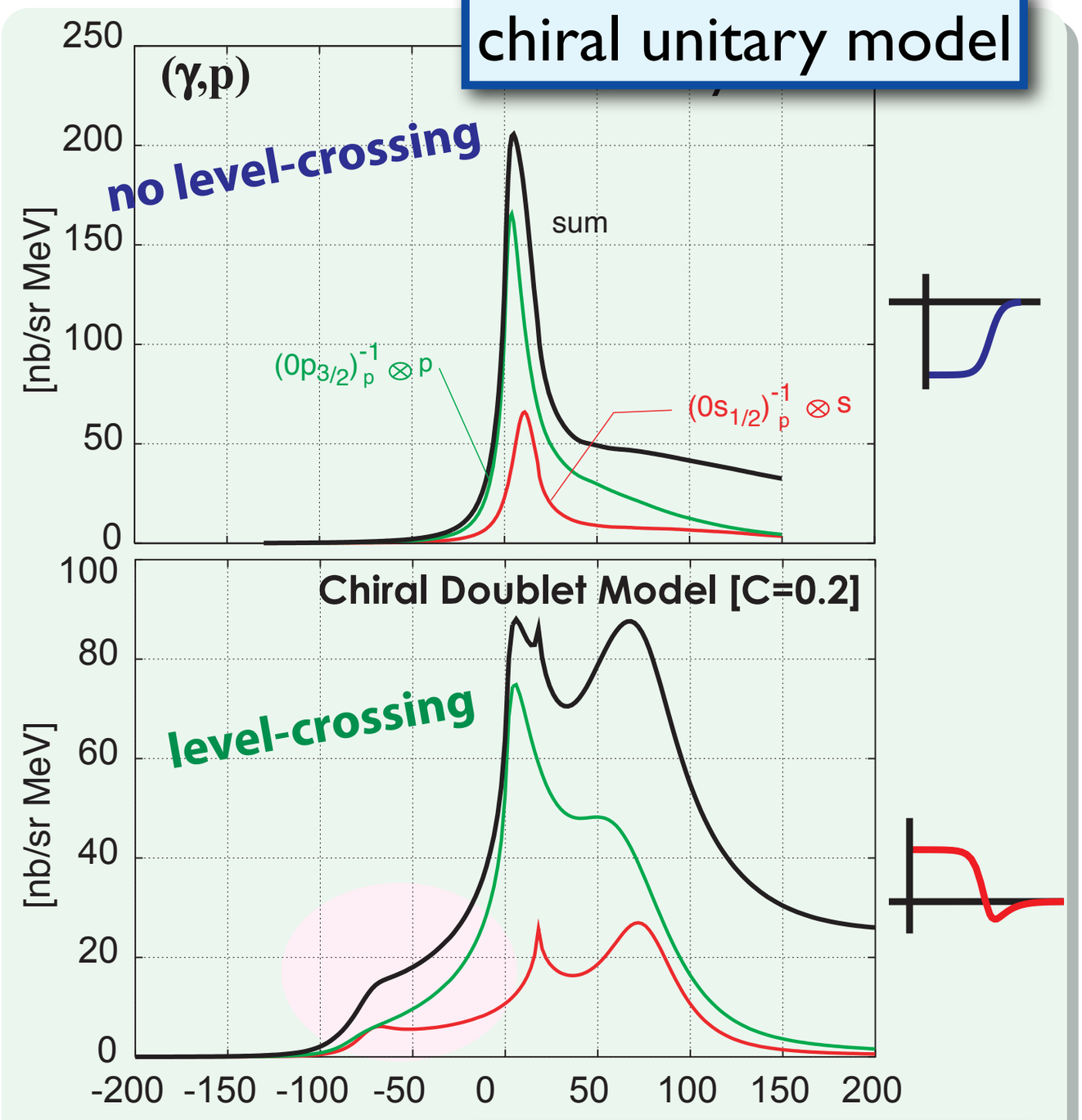

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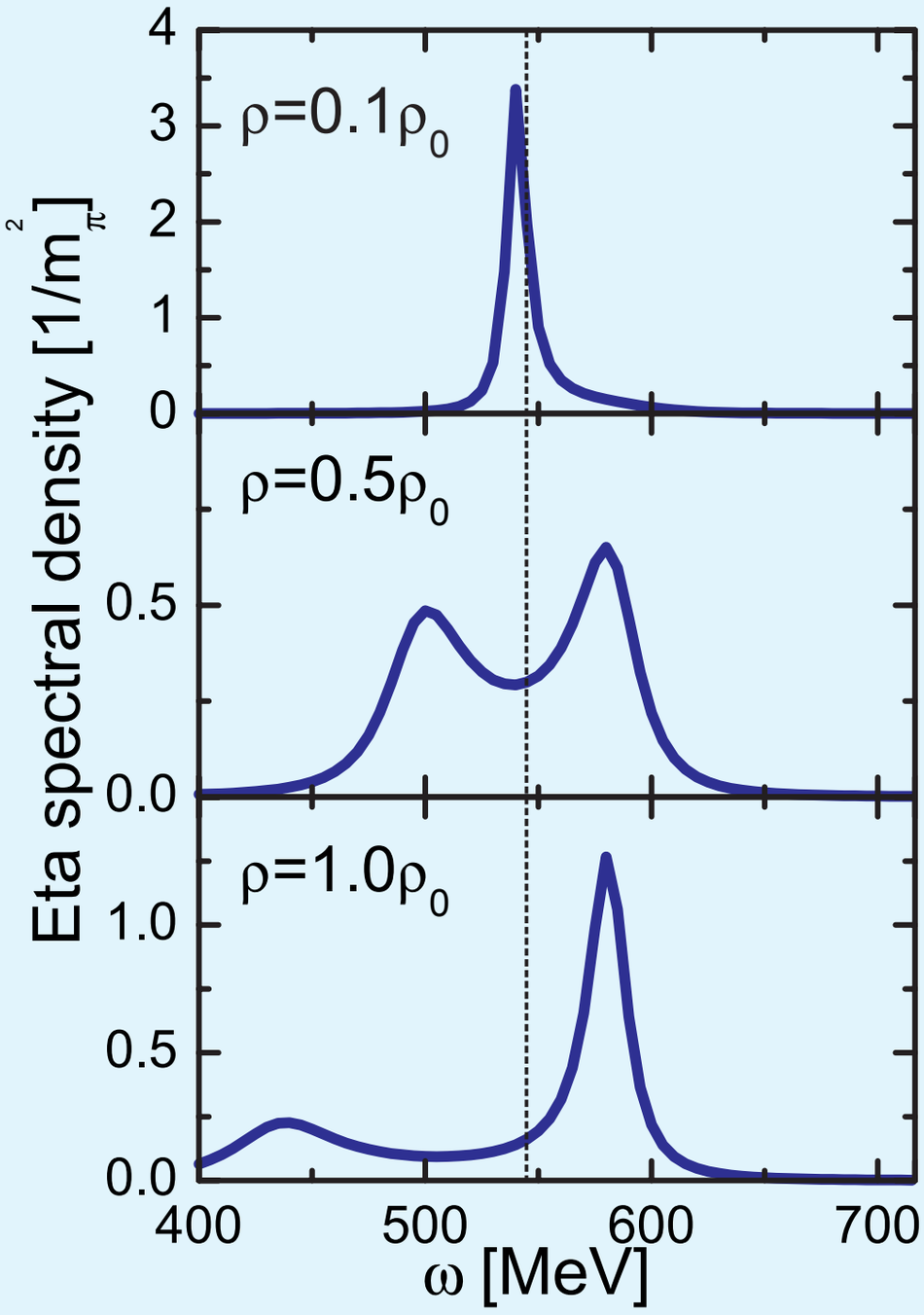

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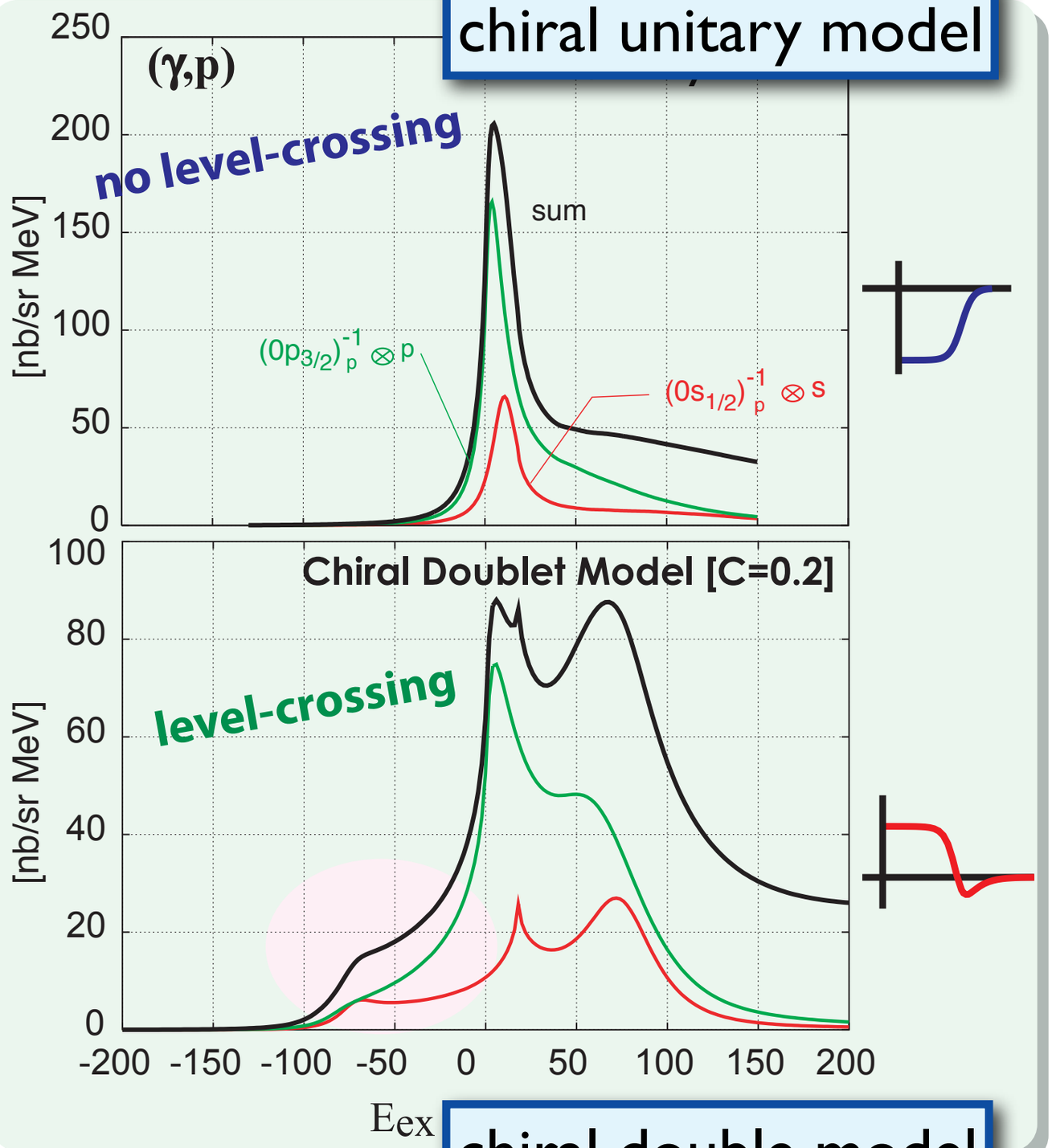

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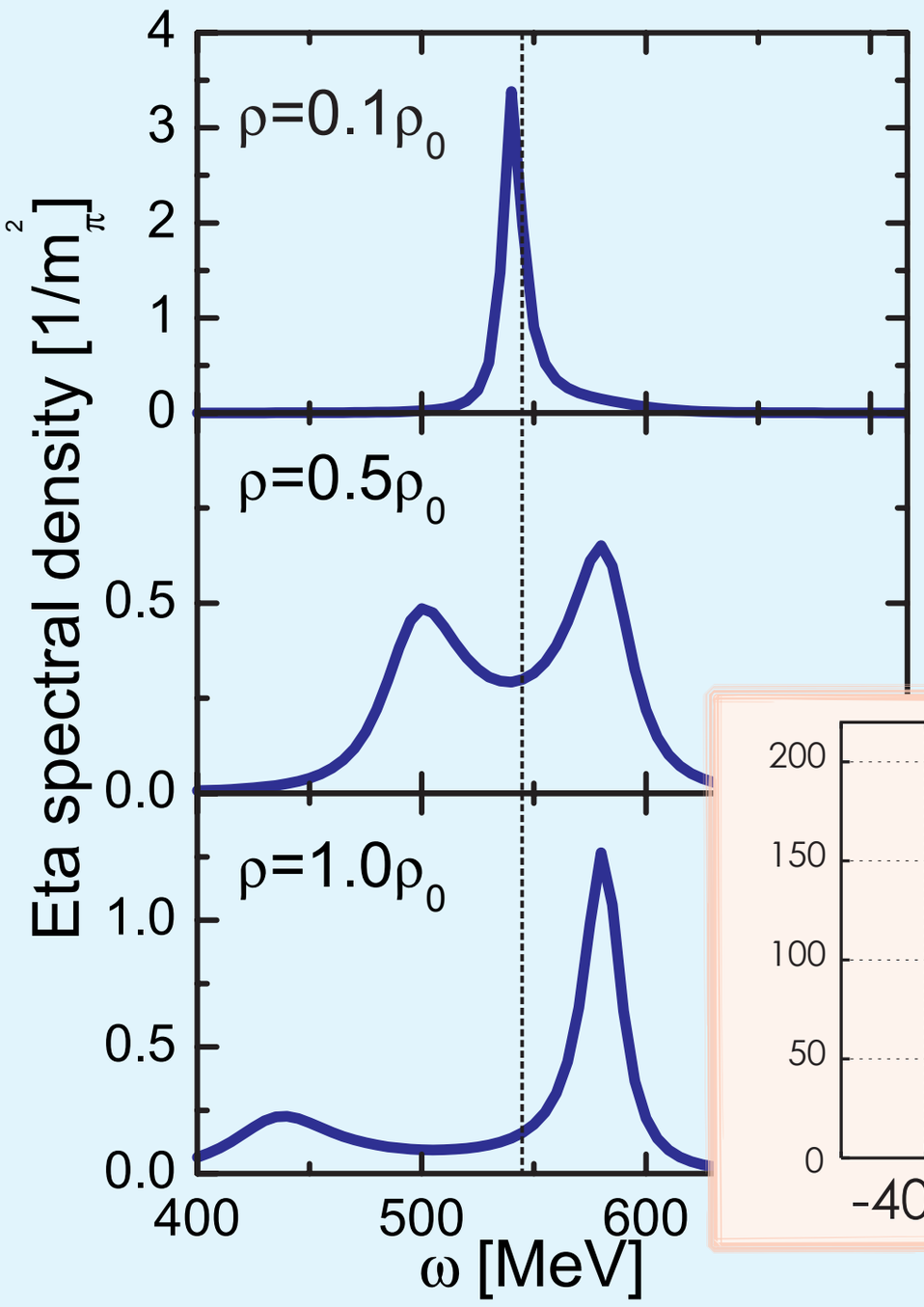

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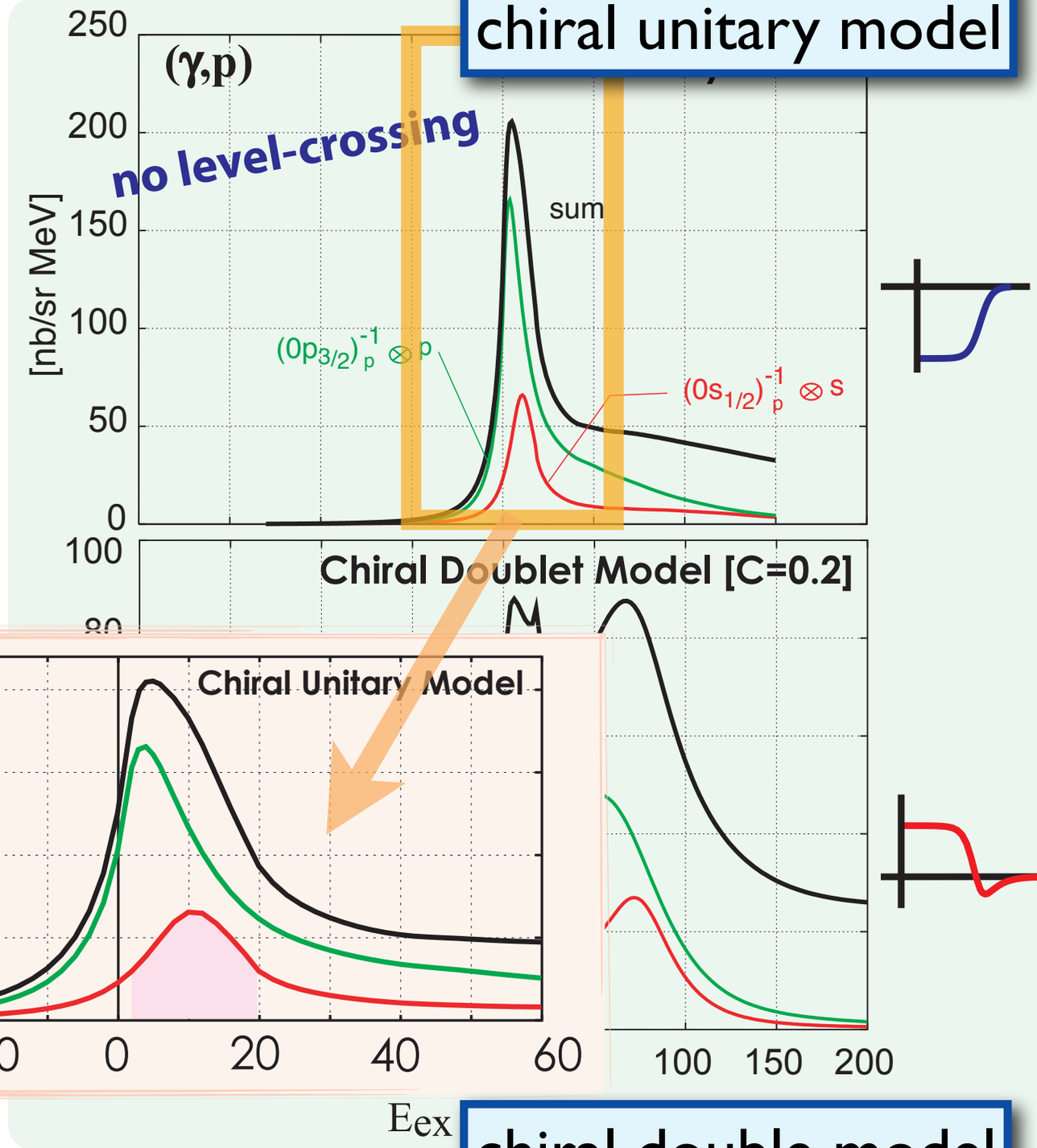

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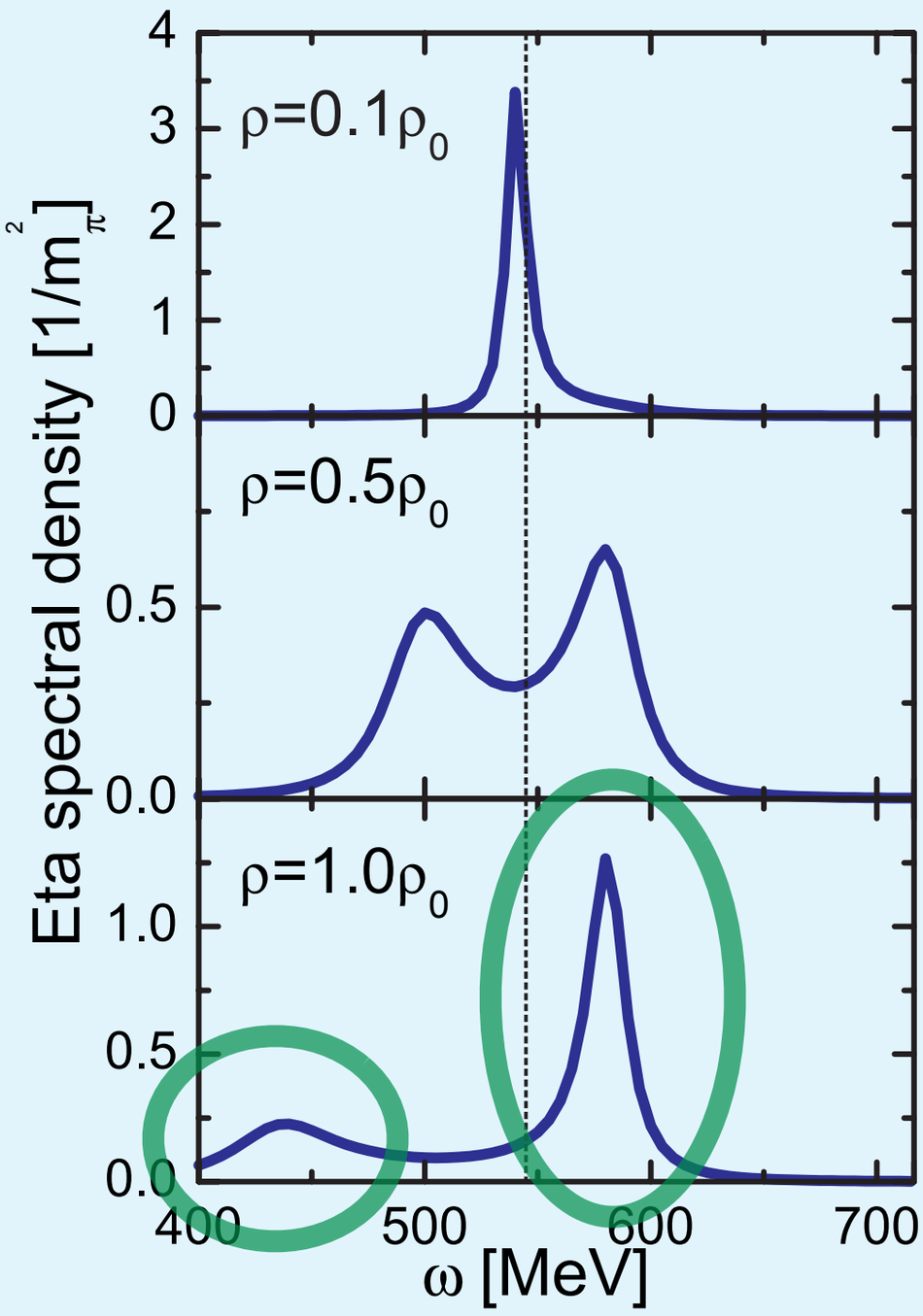

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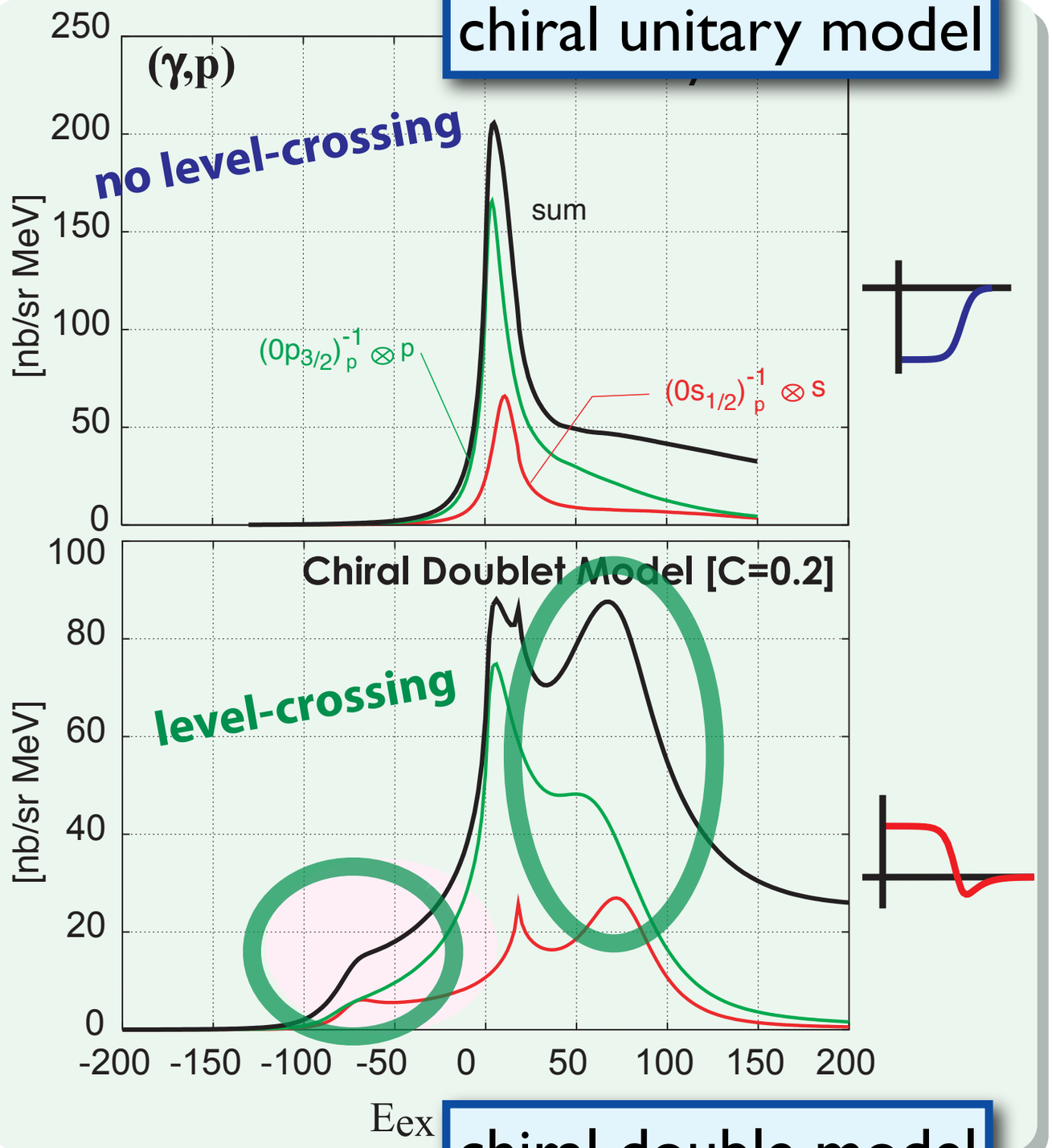

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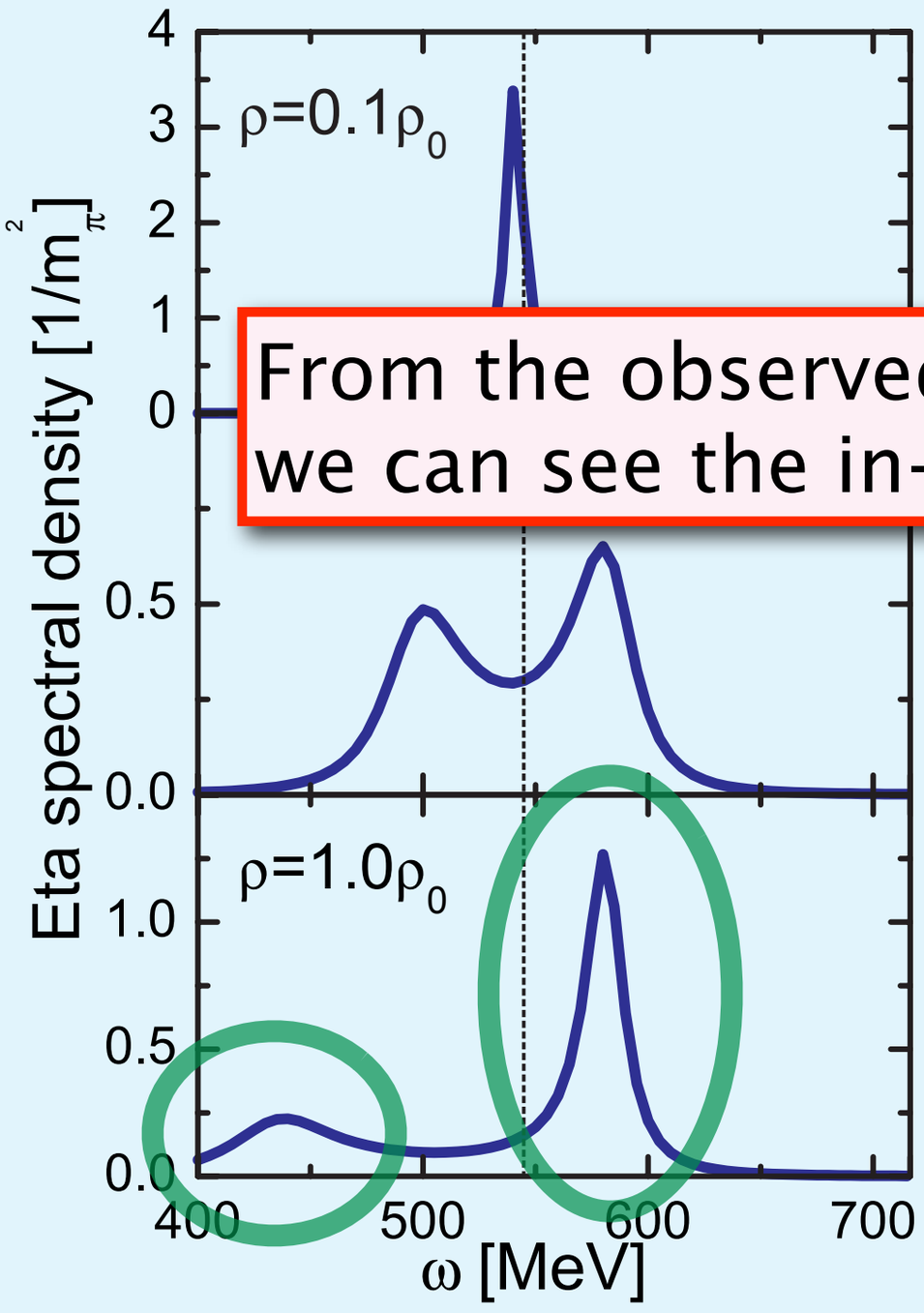

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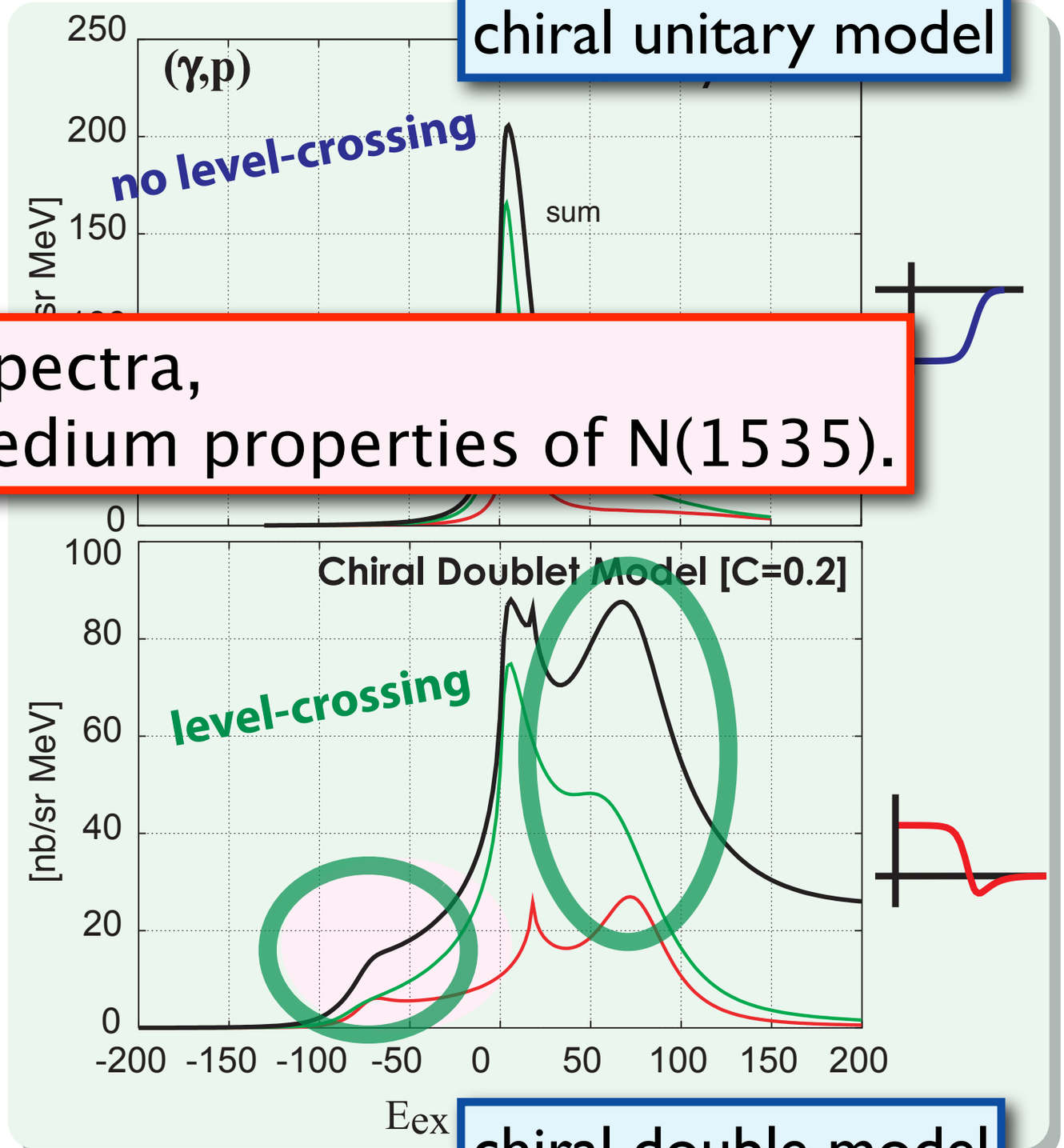

chiral double model

From the observed spectra,
we can see the in-medium properties of N(1535).

details and pion induced case → Nagahiro's talk

Conclusion

The N*-hole contribution is important for the eta meson in nuclear matter and it brings strong energy dependence on the eta self-energy.

Reduction of the mass difference of N* and N as a result of the medium effects induces level crossing of the eta and N*-hole modes, which causes effective change in the spectral function.

The change of the spectral function is observed in formation spectra of eta mesic nuclei.