Nature of excited Ξ baryons as resonances

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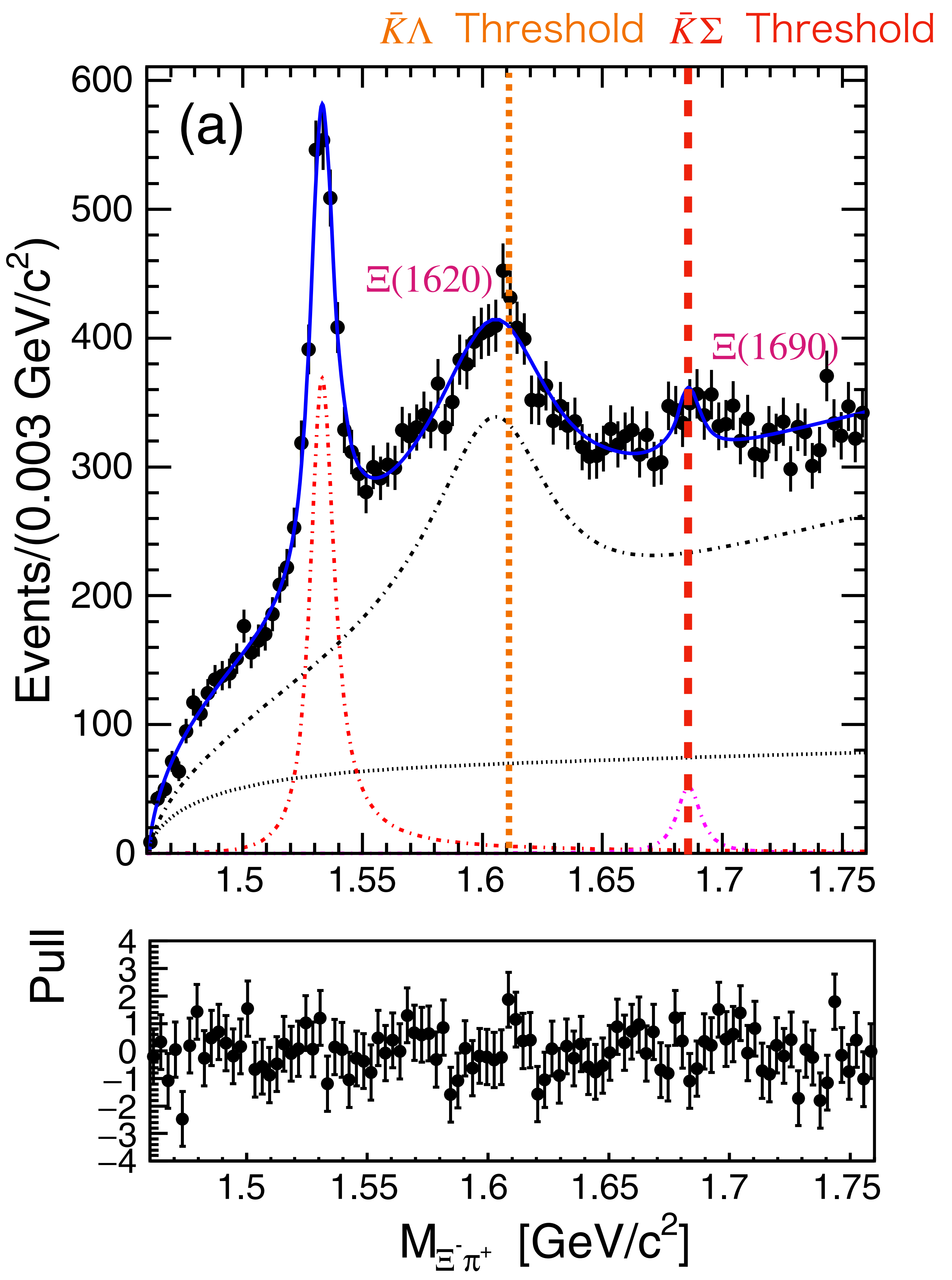
Motivation

- $\Xi(1620)$ and $\Xi(1690)$ peaks in the $\Xi_c \to \pi\pi\Xi$ spectrum by Belle collaboration [1].
- Peaks are close to thresholds of $\bar{K}\Lambda$ and $\bar{K}\Sigma$?
- Aim of this talk
  - Construction of the model of $\Xi(1620)$ which reproduces the Belle data.
  - Study the threshold effect on peak behavior.



Invariant mass distribution of $\pi\Xi$ in the $\Xi_c \to \pi\pi\Xi$ decay [1].

[1]Belle collaboration, M.Sumihama et al., Phys. Rev. Lett. 122, 072501 (2019).

Formulation

Coupled-channel meson-baryon scattering amplitude $T_{ij}(W)$ at total energy W.

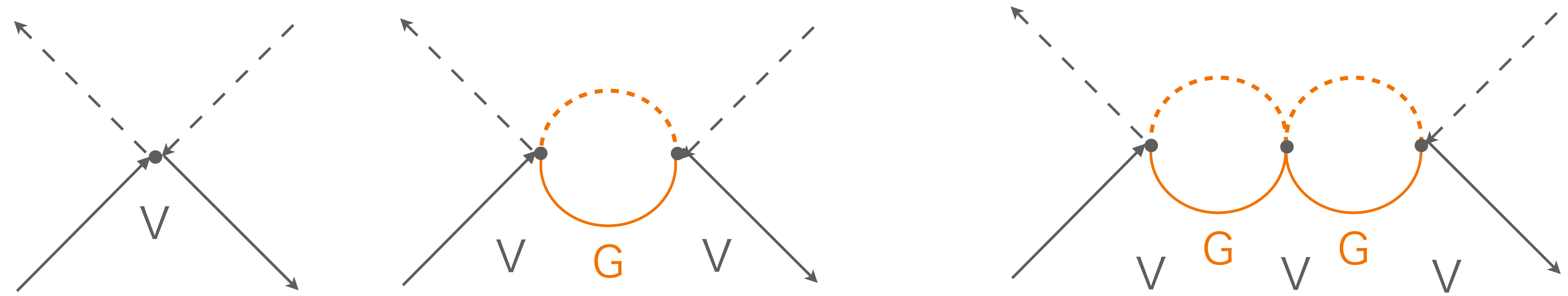
Scattering equation

$$T_{ij}(W) = V_{ij}(W) + V_{ik}(W) G_k(W) T_{kj}(W)$$

$V_{ij}(W)\cdots$Interaction kernel

$G_i(W)\cdots$Loop function

$$T_{ij}(W) = V_{ij}(W) + V_{ik}(W) G_k(W) V_{kj}(W) + V_{ik}(W) G_k(W) V_{kl}(W) G_l(W) V_{lj}(W) + \cdots$$



Meson-baryon multiple scattering

The solution of the equation is obtained as

$$T_{ij}(W) = [[V(W)]^{-1} - G(W)]^{-1}_{ij}$$

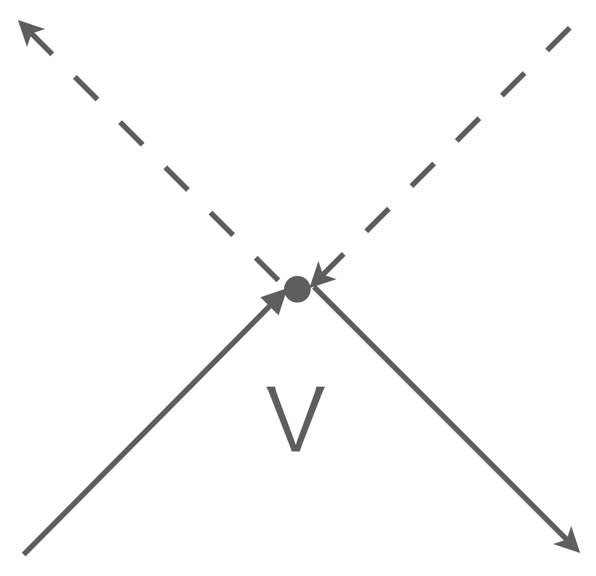
Formulation

$V_{ij}(W)\cdots$Interaction kernel (Weinberg-Tomozawa term)
s-wave interaction satisfying chiral low energy theorem.

$$V_{ij}(W) = -\frac{C_{ij}}{4f_i f_j} N_i N_j (2W - M_i - M_j)$$

f_i : Meson decay constant, C_{ij} : Group theoretical coefficient,

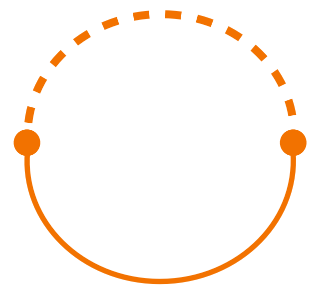
M_i : Baryon Mass, N_i : kinematical coefficient



$G_i(W, a_i)\cdots$Loop function
(Divergence renormalized by dimensional regularization)

$$G_i(W) \to G_i(W, a_i)$$

W:Total energy, a_i:subtraction constant



Scattering amplitude of previous study

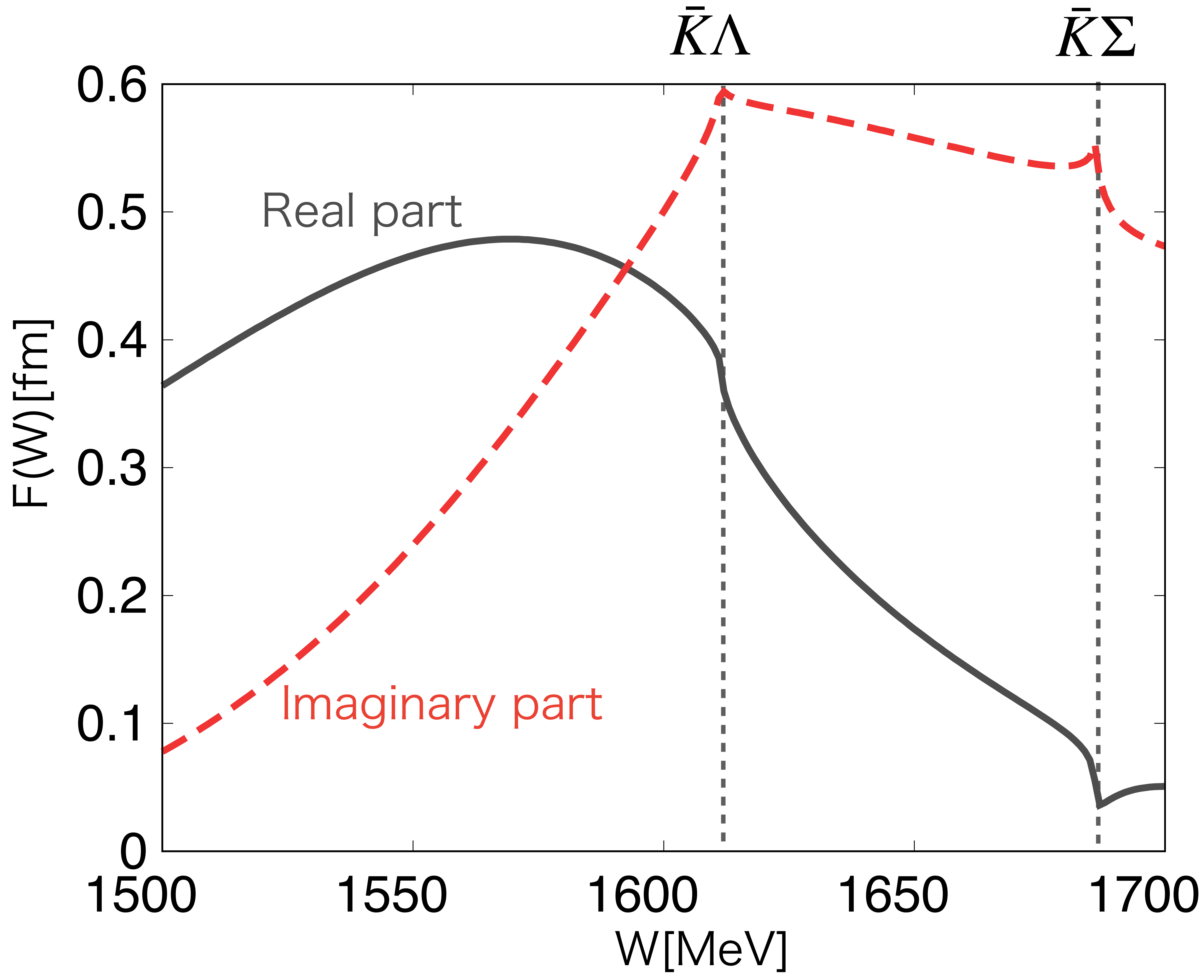
Previous work about $\Xi(1620)$ [2]

$M_R = 1607$ MeV, $\Gamma_R = 280$ MeV.

- Scattering amplitude F of $\pi\Xi$

$$F(W) = -\frac{2M_1T_{11}(W)}{8\pi W}$$

No distinct peak of imaginary part due to broad decay width



[2] A.Ramos, E.Oset and C.Bennhold Phys. Rev. Lett. 89.252001 (2002).

Strategy of model improvement

- Belle result :

$M_R = 1610$ MeV, $\Gamma_R = 60$ MeV

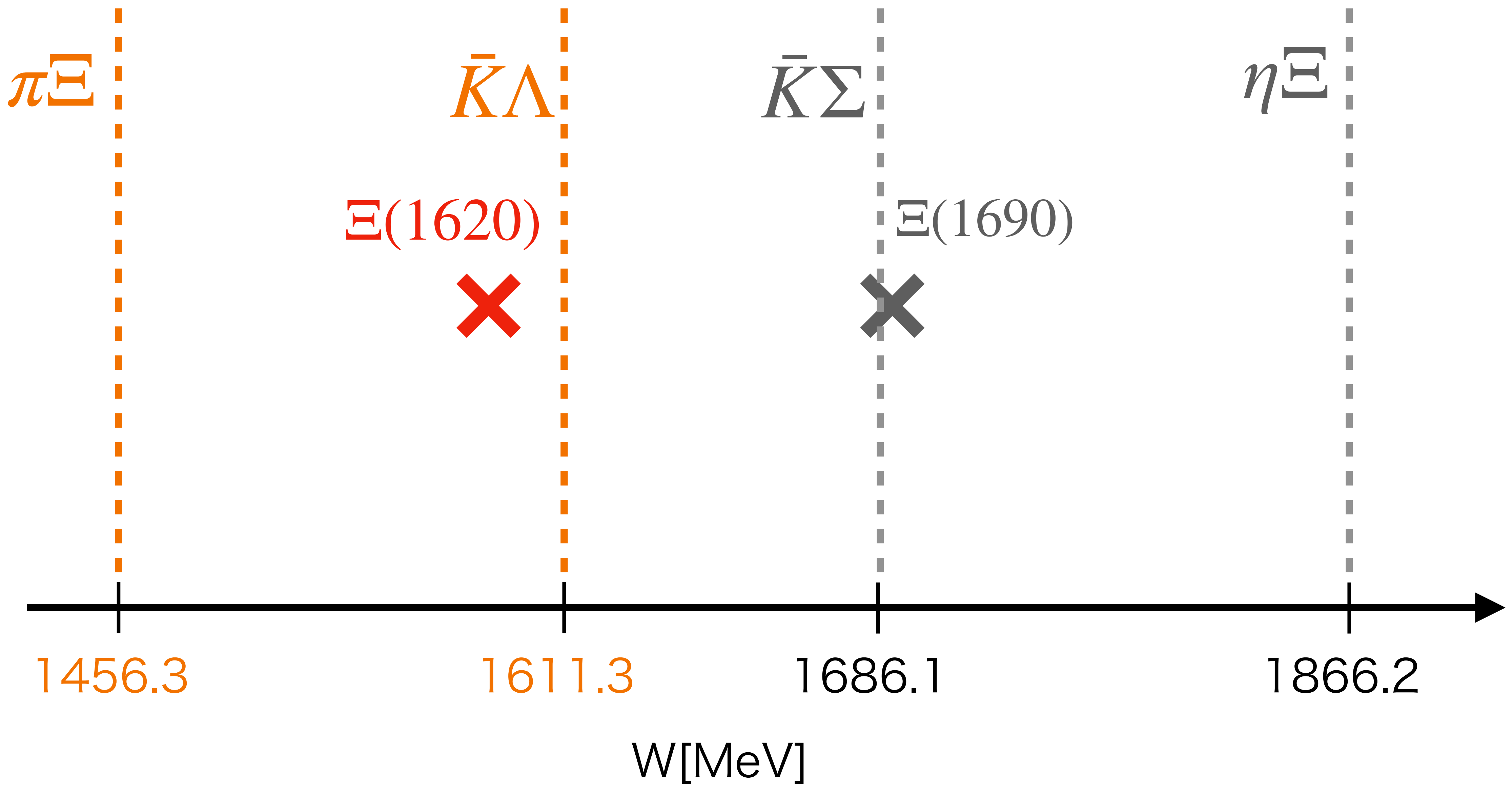
- Based on the peak position, we define

$z_{\text{Belle}} = [1610 - 30i]$ MeV.

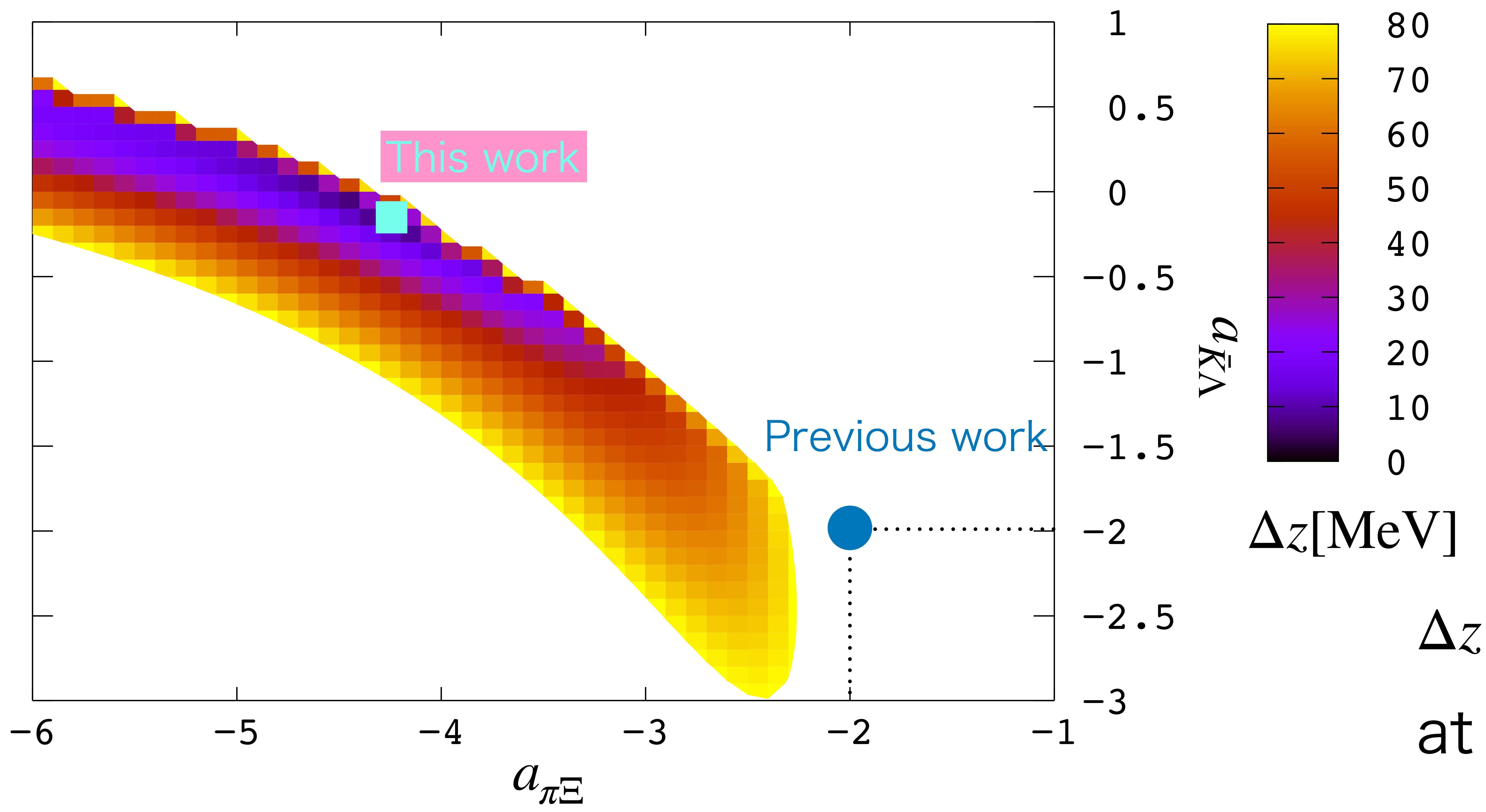
- z_{Th} : Pole in theoretical model

$$\Delta z = |z_{\text{Belle}} - z_{\text{Th}}|$$

- We minimize Δz by adjusting subtraction constants $a_{\pi\Xi}$ and $a_{\bar{K}\Lambda}$.



Δz minimization

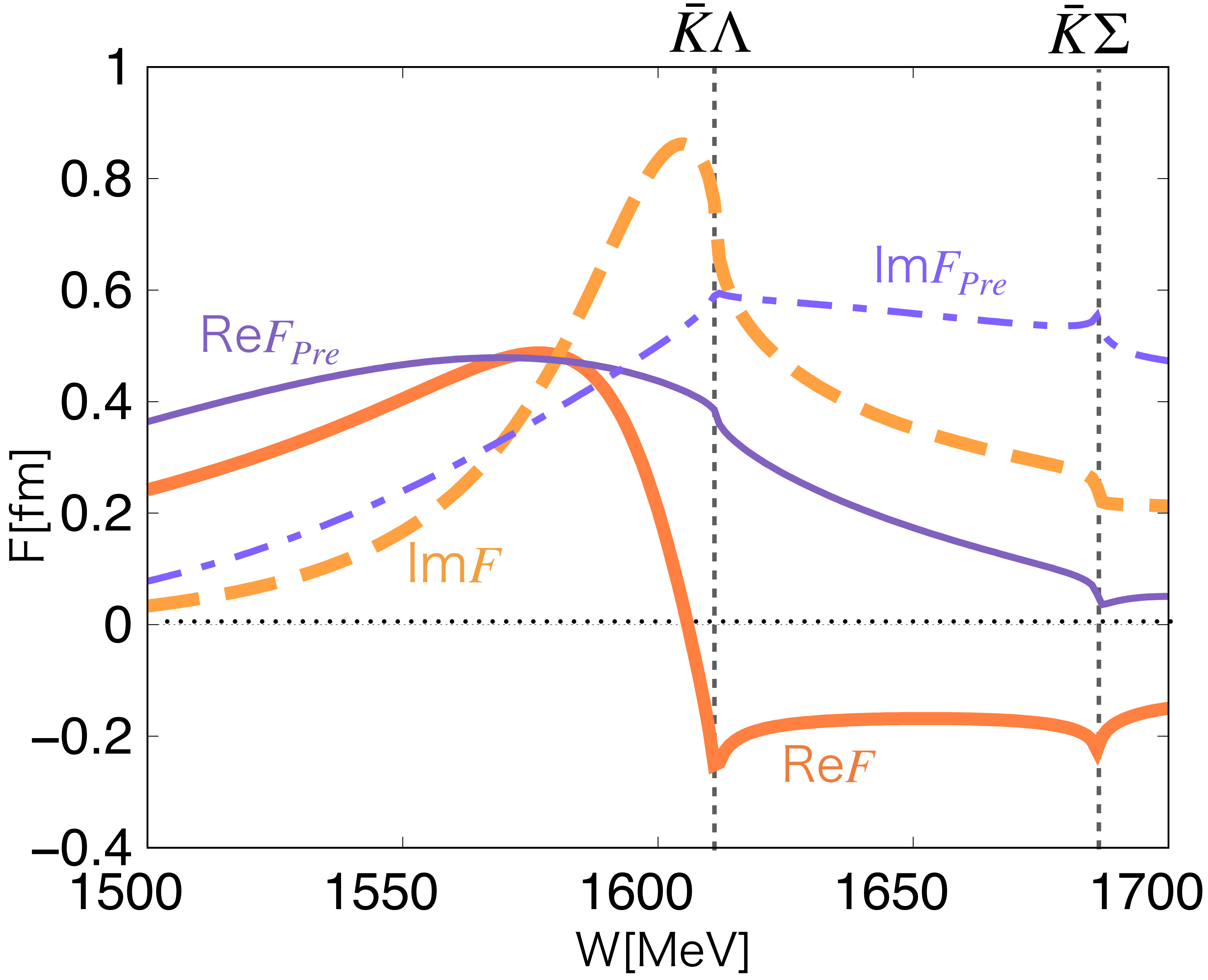


$\Delta z = 0.1\mathrm{MeV}$ is achieved

at $a_{\pi\Xi} = -4.19$ and $a_{\bar{K}\Lambda} = -0.14$.

Comparison with previous study

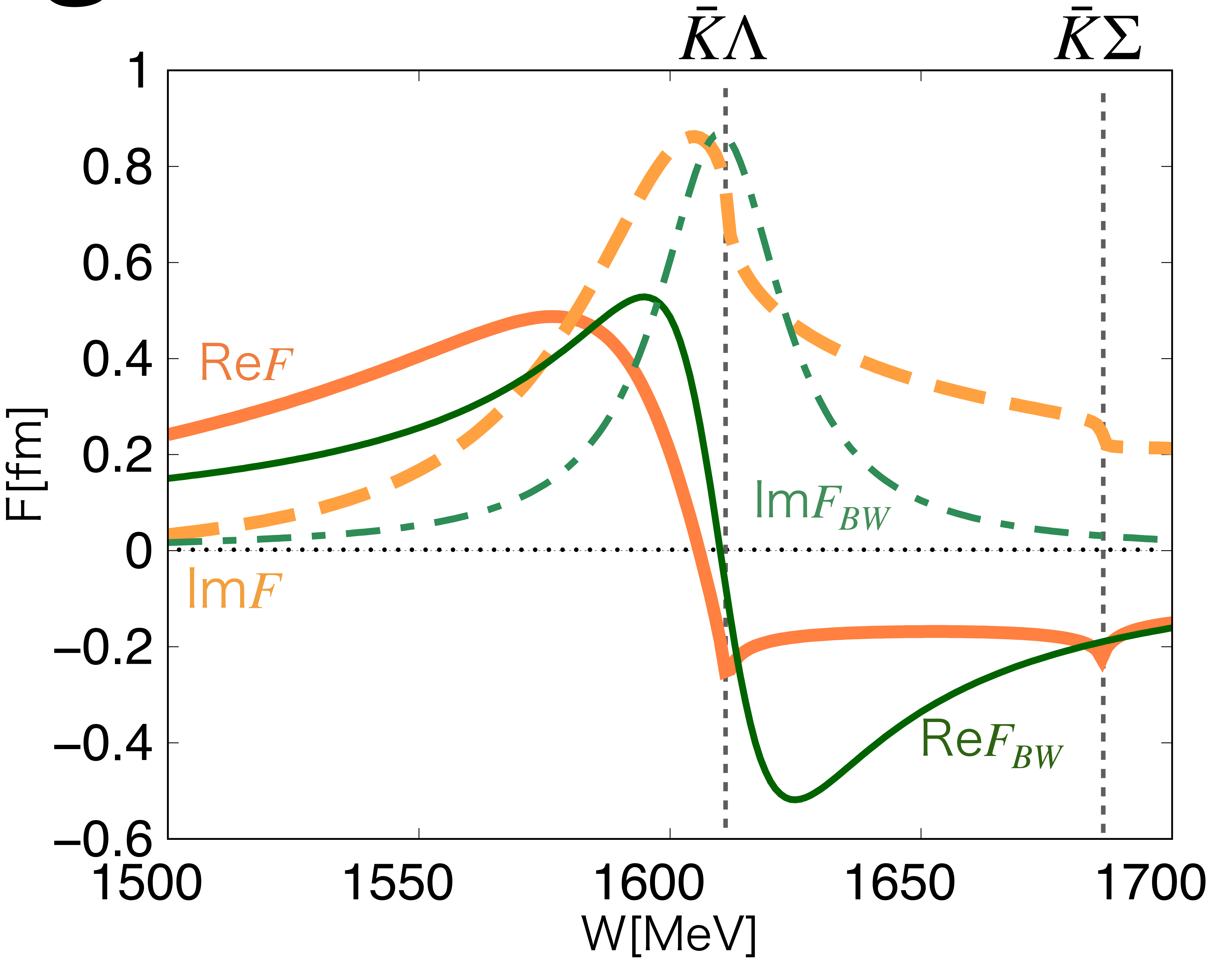
- $\Xi(1620)$This study (Thick lines)
- previous study(Thin lines)
- In the previous study…imaginary part has no distinct peaks due to broad decay width. In this study, distinct peak appears in imaginary part by narrow width.



➡ There is a distinct peak on real axis like Belle result.

Comparison with Breit-Wigner distribution

- Real and imaginary parts of the scattering amplitude (Thick lines).
- Breit-Wigner distribution with a pole at the same position (Thin lines).
- The peak position is shifted and the shape is distorted by the threshold effect.



→ We found that imaginary part of scattering amplitude is shifted by threshold effect.

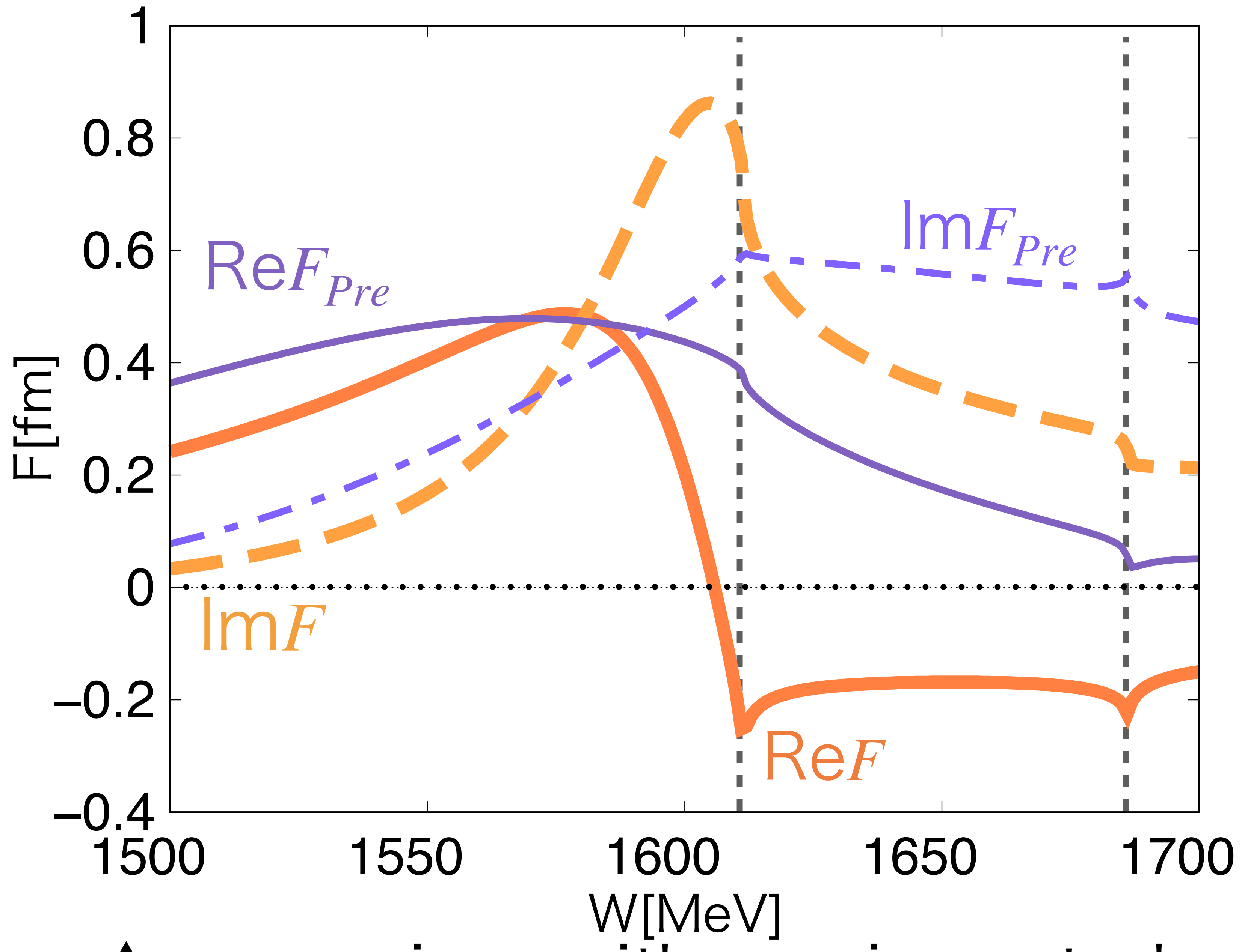
Summary

- We construct the coupled-channel scattering amplitude with $\Xi(1620)$ peak as reported by Belle collaboration.

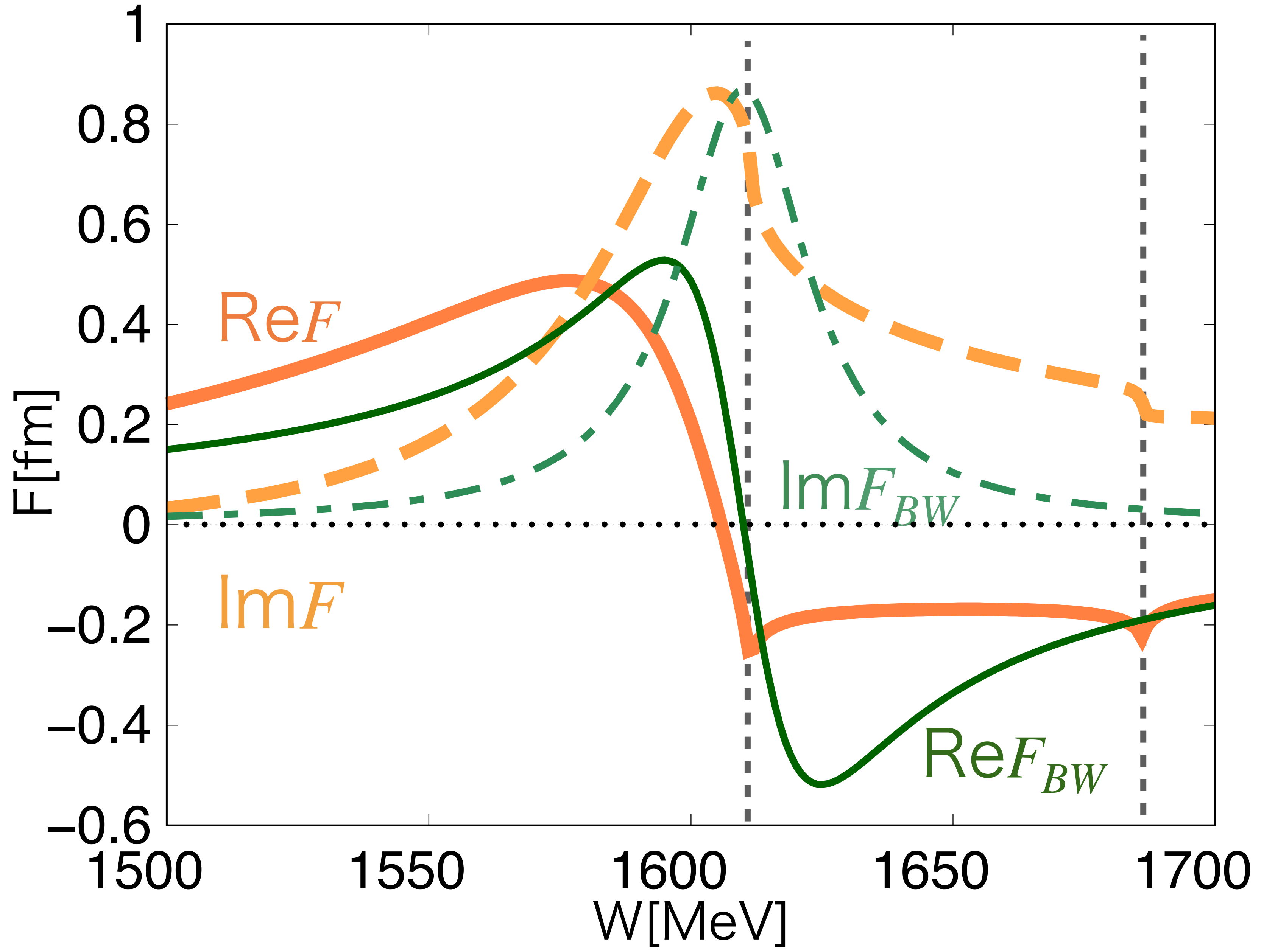
- In comparison with the Breit-Wigner distribution, we find that the near-threshold resonance peak is distorted by the threshold effect.

  → Caution must be paid to determine the resonance pole near the threshold.

- Future plan: study of $\Xi(1690)$, calculation of $\Xi_c \to \pi\pi\Xi$ decay.



▲comparison with previous study



▲comparison with Breit-Wigner distribution