Exclusive formation spectra of kaonic nuclei with chiral unitary amplitude

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Introduction

- Kaonic Nuclei

  -- ^{12}C, ^{16}O Theor. : Yamagata, Nagahiro, Hirenzaki(Structure, Reaction)
  : Mares, Friedman, Gal (Structure)
  Exp. : Kishimoto, Hayakawa -- Osaka Group

  -- ^{4}He Theor. : Akaishi, Yamazaki, Dote (Structure)
  Exp. : Iwasaki, Suzuki -- RIKEN Group

Many Subcomponents
Large Widths

➔ It seems <u>difficult to observe clear signals</u> for these kaonic nuclei.

J-PARC

- $^{3}He(K^{-},n)K^{-}pp$ J-PARC E15, Iwasaki, Nagae

  -- Signals for kaonic nuclei ? (even with large width?)
  (only a few subcomponents)

- Many Theoretical Studies for $K^{-}pp$ bound states.

We want to know the shapes of the spectra
for the formation of $\bar{K}NN$ states!!

In today's talk…

Yamagata, Nagahiro, Okumura, Hirenzaki, PTP114(05)301 ; Errata 114(05)905
Yamagata, Nagahiro, Hirenzaki, PRC74(06)014604
Yamagata, Hirenzaki, EPJA31(07)255
Yamagata, Nagahiro, Kimura, Hirenzaki PRC76(07)045204

- $\bar{K}$NN systems

  - Formation spectra in Green's function method

    T. Koike, T. Harada , PLB 652(07)262, NPA 804(08)231.

    - $\bar{K}$ - NN optical potential evaluated by chiral amplitudes
    - Consider all possible two nucleons and $\bar{K}$ systems
    - Include the contributions from $\bar{K}^0$ initiated process.

novelty !!

$^3\mathrm{He}(K^-,n)$	$^3\mathrm{He}(K^-,p)$	$t(K^-,n)$	$t(K^-,p)$
K^-pp	K^-pn	K^-pn	K^-nn
$\bar{K}^0pn$		$\bar{K}^0nn$	

We show the missing mass spectra accompanied by the particle emissions due to Kbar absorption in nucleus.
We also consider p-wave optical potential to take account of $\Sigma(1385)$ resonance effects.

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Yamagata, Nagahiro, Okumura, Hirenzaki,
PTP114(05)301 ; Errata 114(05)905
Yamagata, Nagahiro, Hirenzaki,
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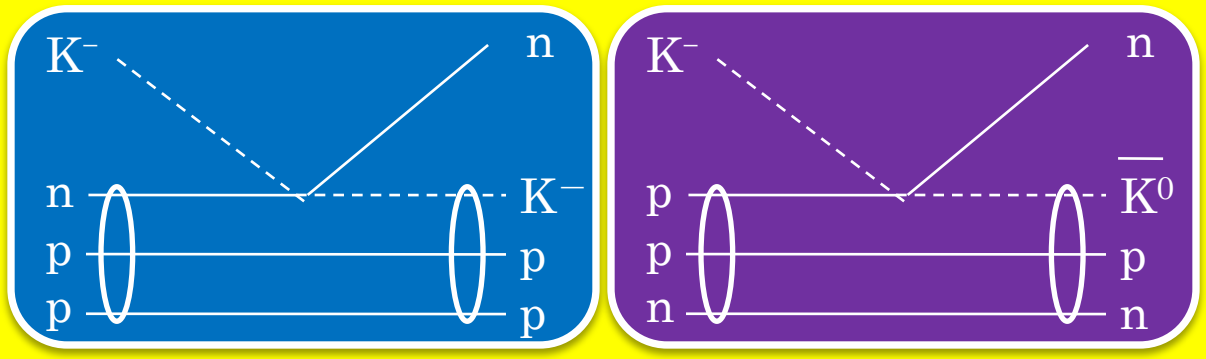
- $\overline{\mathrm{K}}$N
  - K
    ke, T. Harada ,
    52(07)262,
    304(08)231.



novelty !!

$^3\mathrm{He}(K^-,n)$	$^3\mathrm{He}(K^-,p)$	$t(K^-,n)$	$t(K^-,p)$
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We show the missing mass spectra accompanied
by the particle emissions due to Kbar absorption in nucleus.
We also consider p-wave optical potential to take account of
Σ(1385) resonance effects.

Our theoretical tools

- 複素エネルギー平面上でKlein-Gordon方程式を
  エネルギーについてselfconsistentになるように解く。

E. Oset and L. L. Salcedo, J. Comput. Phys. 57 (85) 361

$$[-\vec{\nabla}^2 + \mu^2 + 2\mu V_{\rm opt}(r,\omega)]\phi(\vec{r}) = [\omega - V_{\rm coul}(r)]^2\phi(\vec{r})$$

- Green's function methodを用いて生成スペクトラムを計算

O. Morimatsu, K. Yazaki, NPA435(85)727, NPA483(88)493

$$\frac{d^2\sigma}{dEd\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\bar{K}N\to N\bar{K}} \sum_\alpha -\frac{1}{\pi}\mathrm{Im}\int d\vec{r}d\vec{r}'\, f_\alpha^*(\vec{r}')G(E;\vec{r}',\vec{r})f_\alpha(\vec{r})$$

$\left(\frac{d\sigma}{d\Omega}\right)_{\bar{K}N\to N\bar{K}}$: Elementary cross section (Exp. data)

$G(E;\vec{r}',\vec{r})$: Green function for K interacting with the nucleus

1-1. Optical Potential

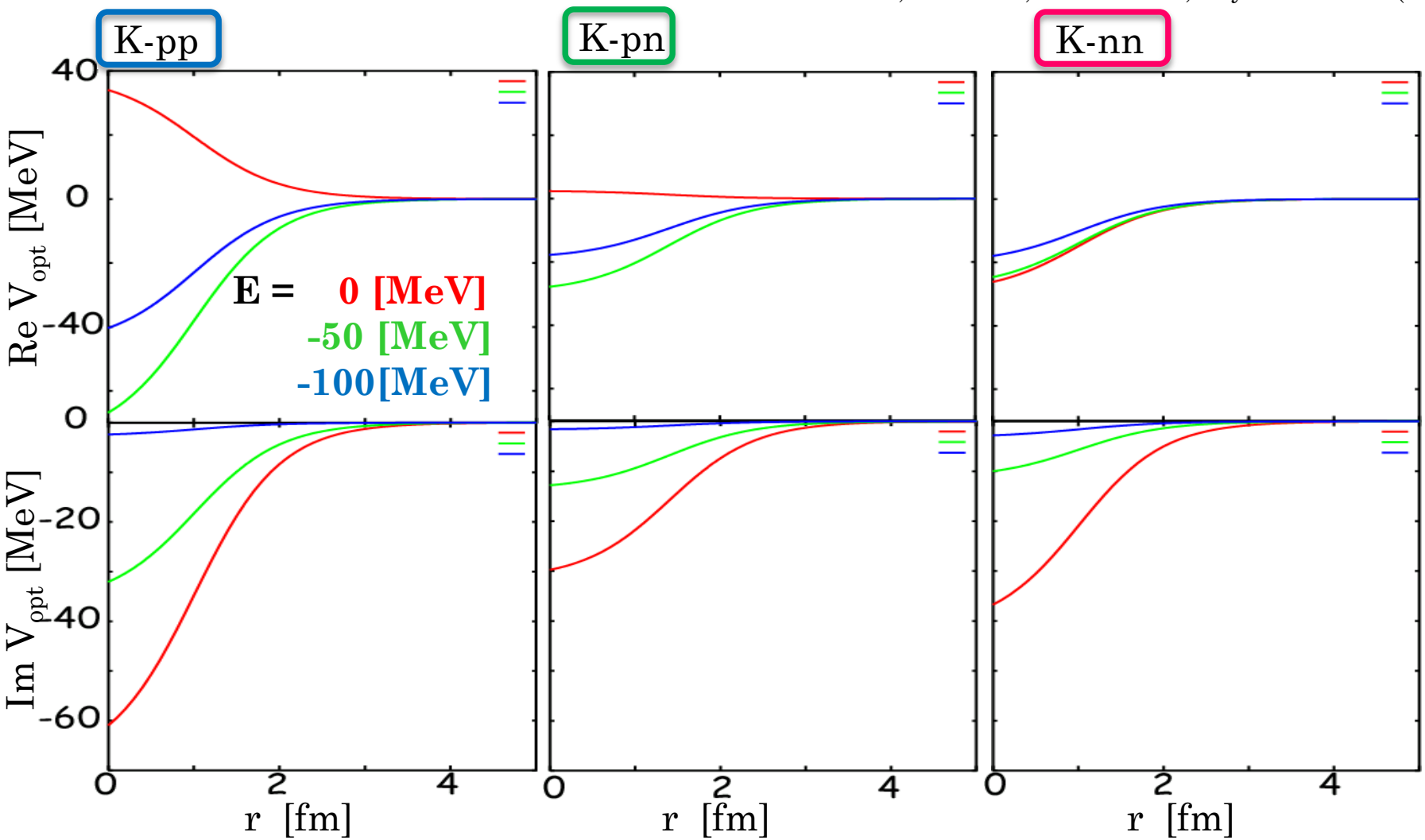
Tρ approximation.

$\frac{A-1}{A}$ factor (To avoid double counting)

only **1 body absorption**.

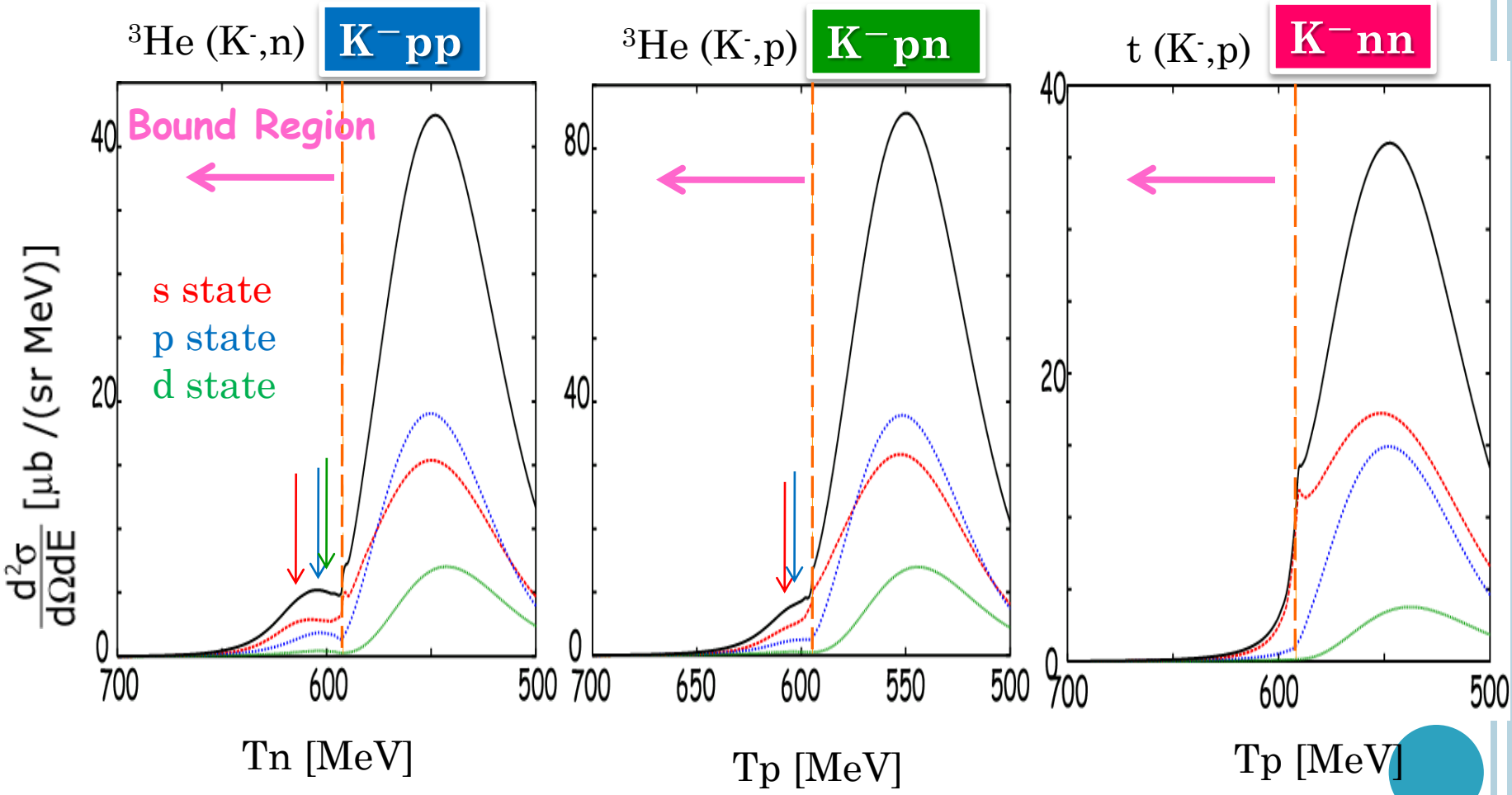
- Chiral Unitary Model

E. Oset, A. Ramos, Nucl. Phys. A635 (98)99
E. Oset, A. Ramos, C. Bennhold, Phys. Lett. B527(02)99



1-2. Results -- Formation Spectra

- Formation Spectra -- Chiral Unitary -- $T(\rho=0,E)\rho(r)$ Linear density

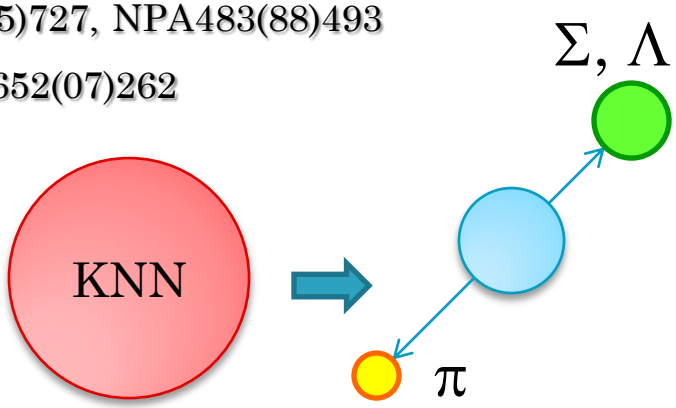


We may observe the contributions from the formation of $\bar{K}NN$ systems!!

1-3. Conversion Part

O. Morimatsu, K. Yazaki, NPA435(85)727, NPA483(88)493

T. Koike, T. Harada , Phys. Lett. B 652(07)262



- Green's function method

*** Total Spectra**

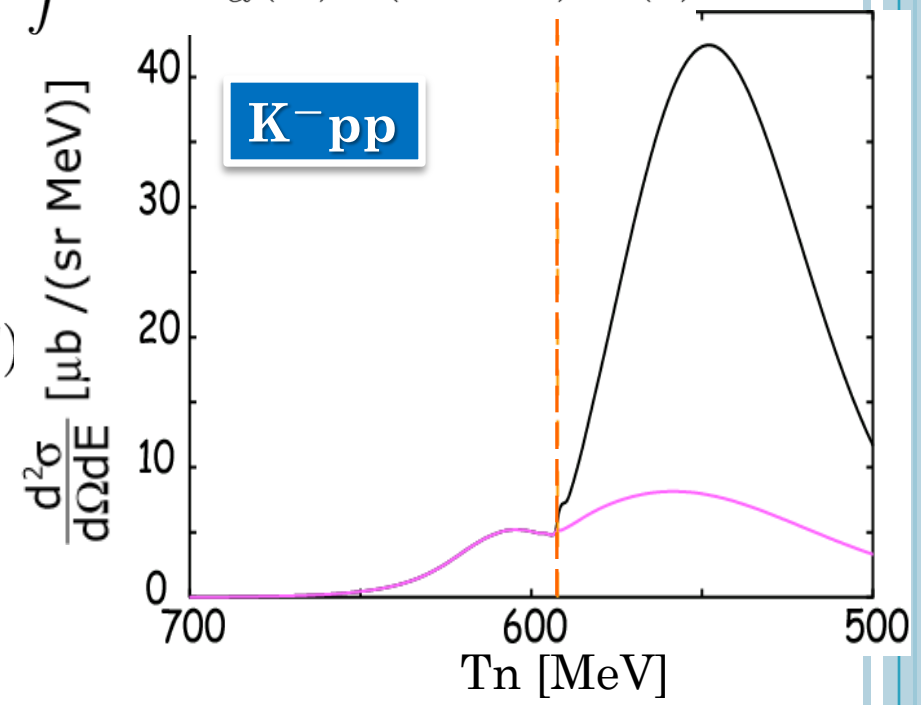
$$\left(\frac{d^2\sigma}{dEd\Omega}\right)_{\rm tot} = \frac{1}{\pi}\left(\frac{d\sigma}{d\Omega}\right)_{\bar{K}N\to\bar{K}N} S_{\rm tot}(E)$$

$$S_{\rm tot}(E) = -\tilde{f}\,{\rm Im}G\ f \quad = -\sum_\alpha {\rm Im}\int d\mathbf{r}d\mathbf{r}' f^*_\alpha(\mathbf{r}')G(E;\mathbf{r}',\mathbf{r})f_\alpha(\mathbf{r})$$

*** Conversion Part**

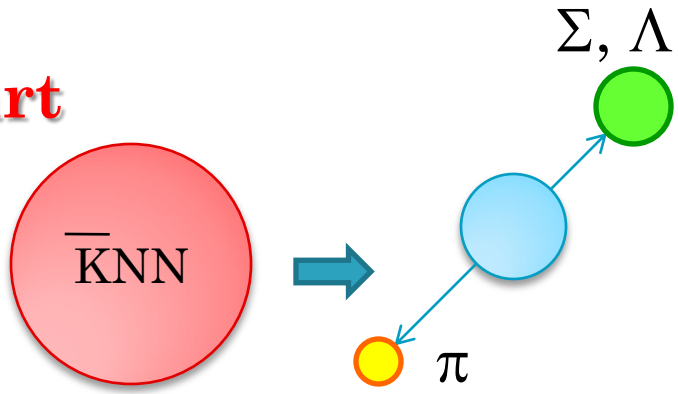
$$\left(\frac{d^2\sigma}{dEd\Omega}\right)_{\rm con} = \frac{1}{\pi}\left(\frac{d\sigma}{d\Omega}\right)_{\bar{K}N\to\bar{K}N} S_{\rm con}(E)$$

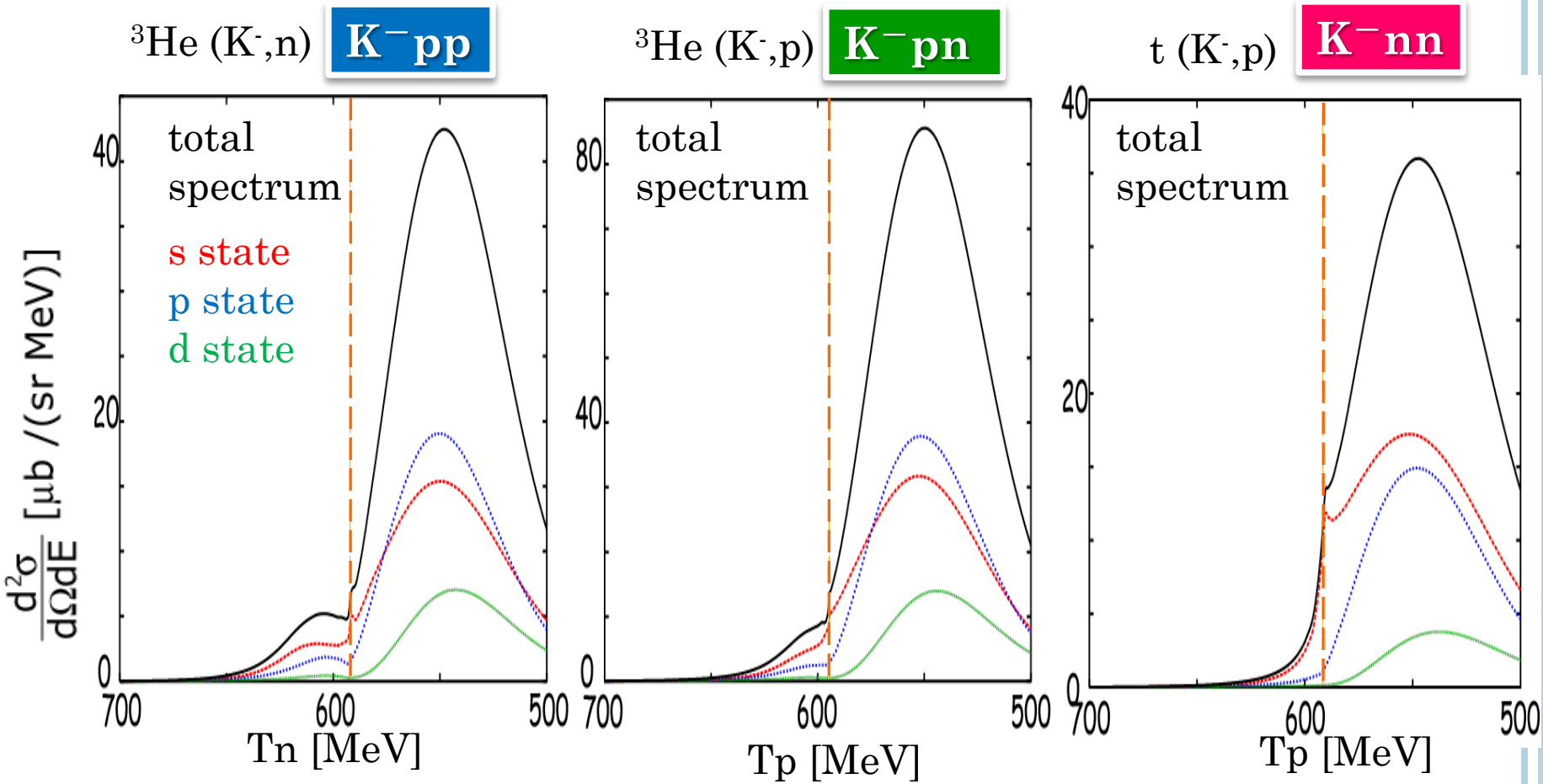
$$S_{\rm con}(E) = -\tilde{f}G^+{\rm Im}U\ G\ f$$



1-4. Results -- Conversion Part

- If we can observe contributions from 1 body absorption process…





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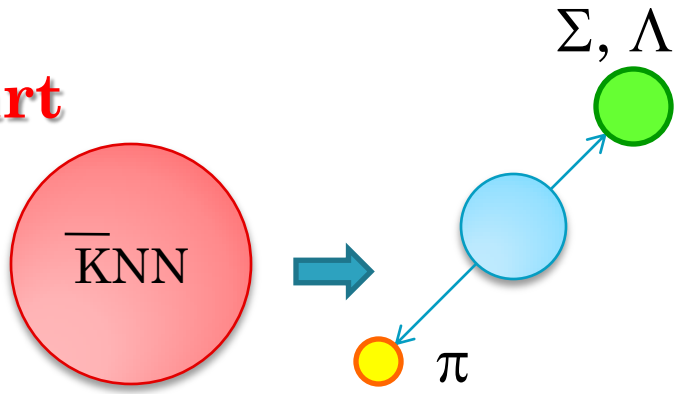

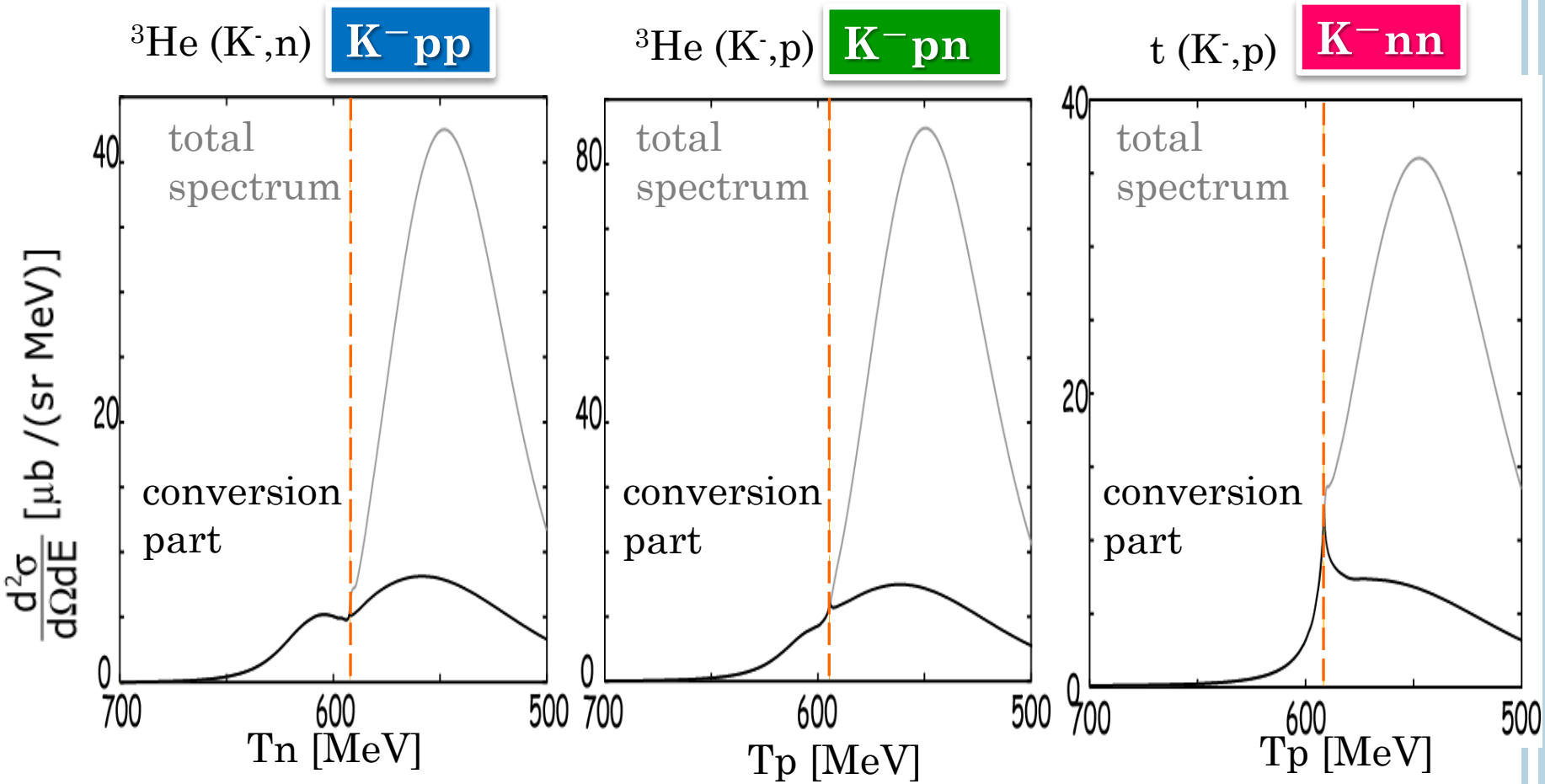

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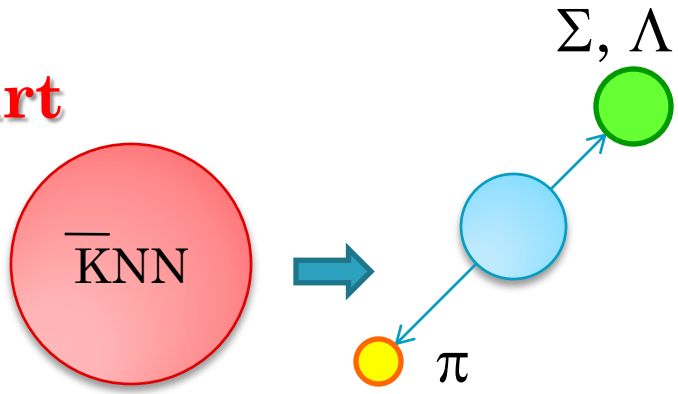

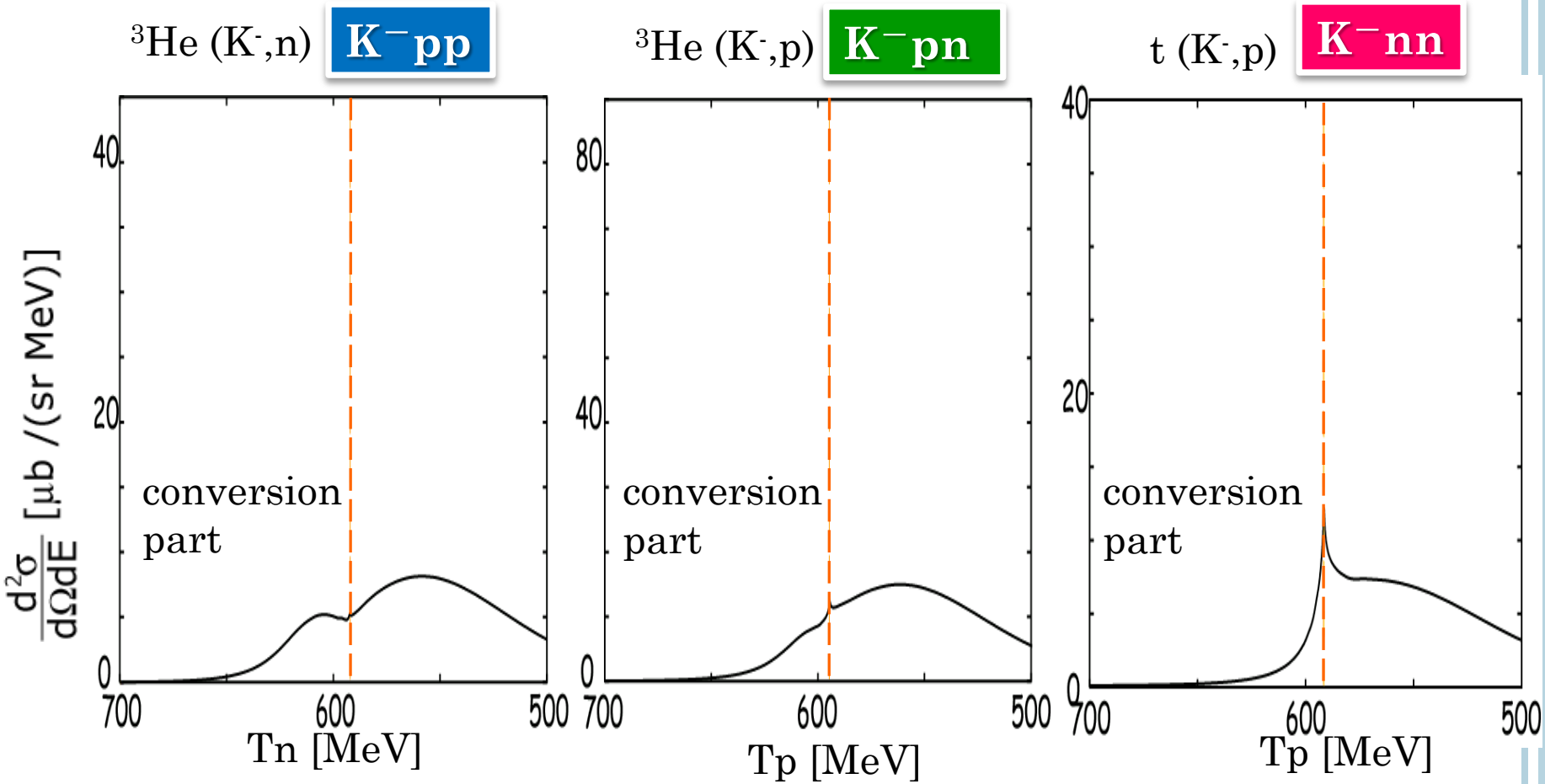

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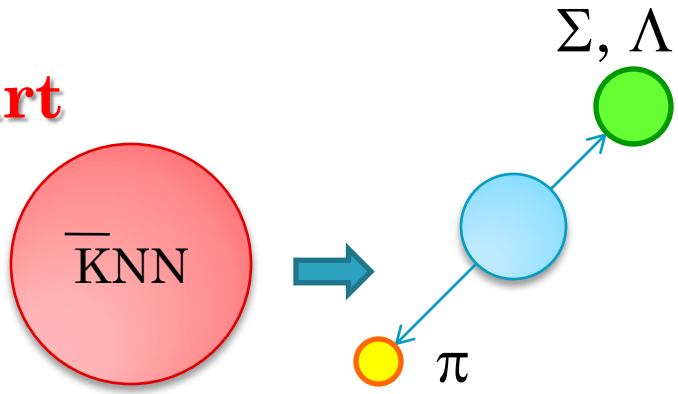
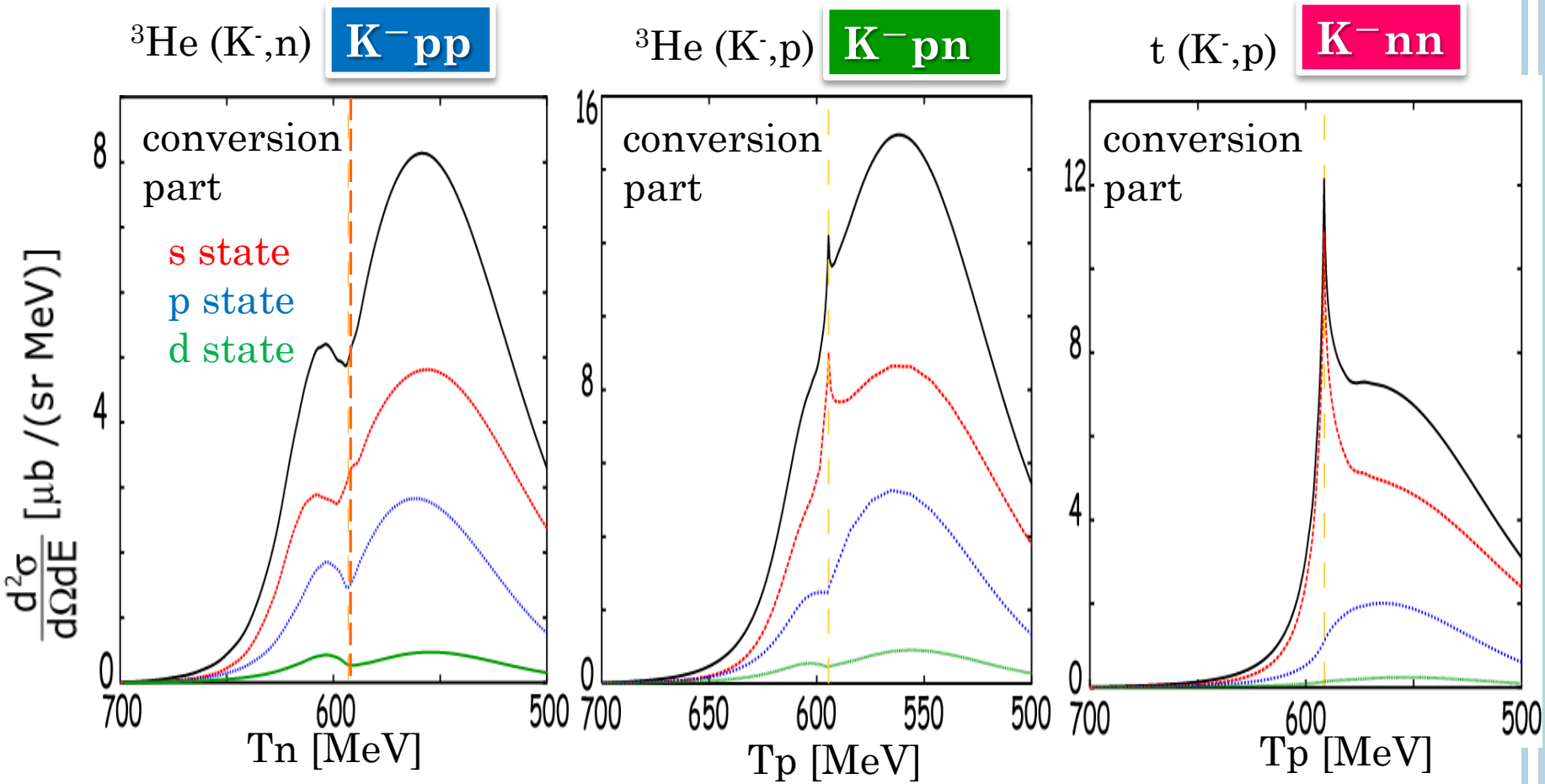
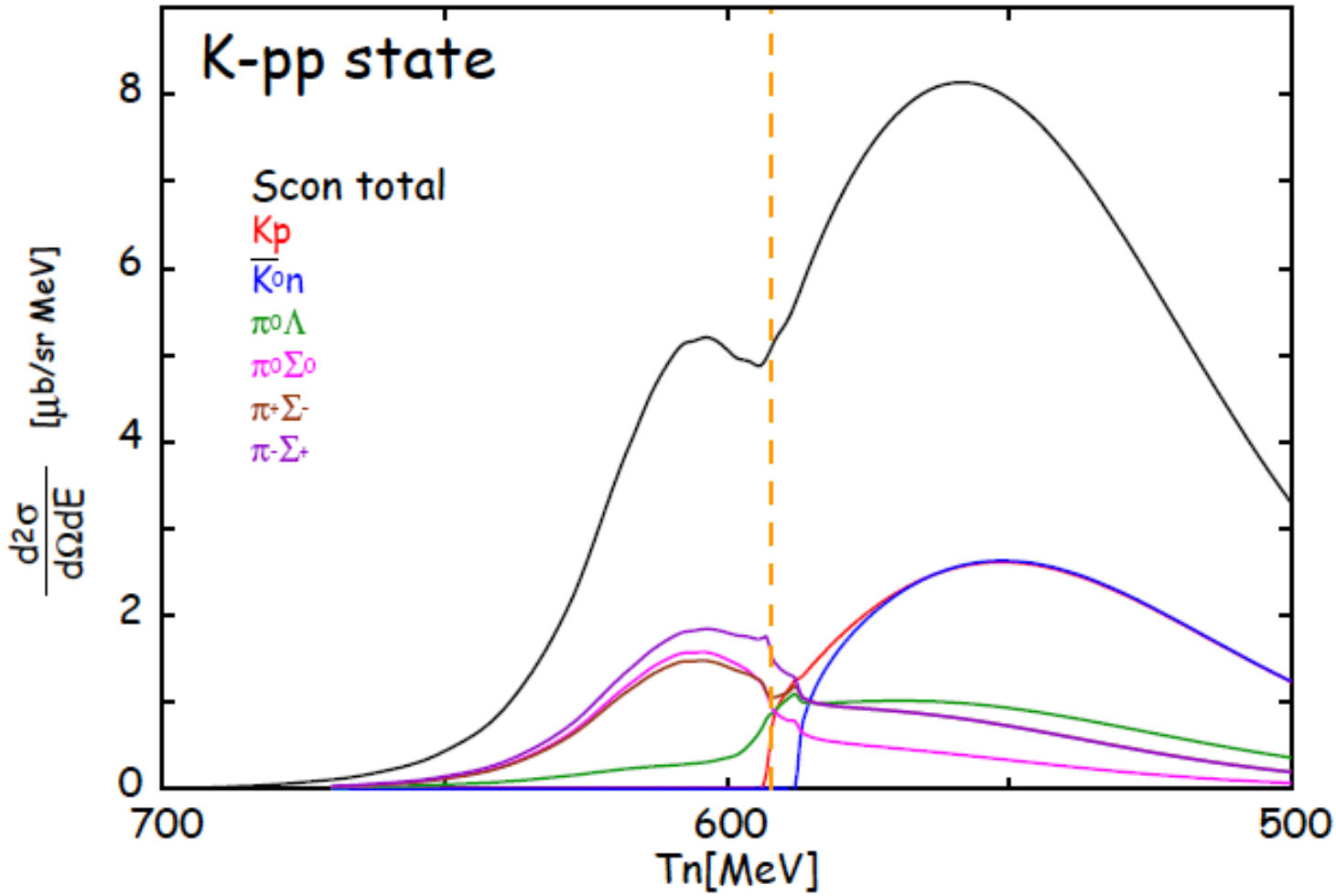




1-4. Results -- **Conversion Part**

- If we can observe contributions

  from 1 body absorption process… ^{3}He (K^{-},n) **$K^{-}pp$**



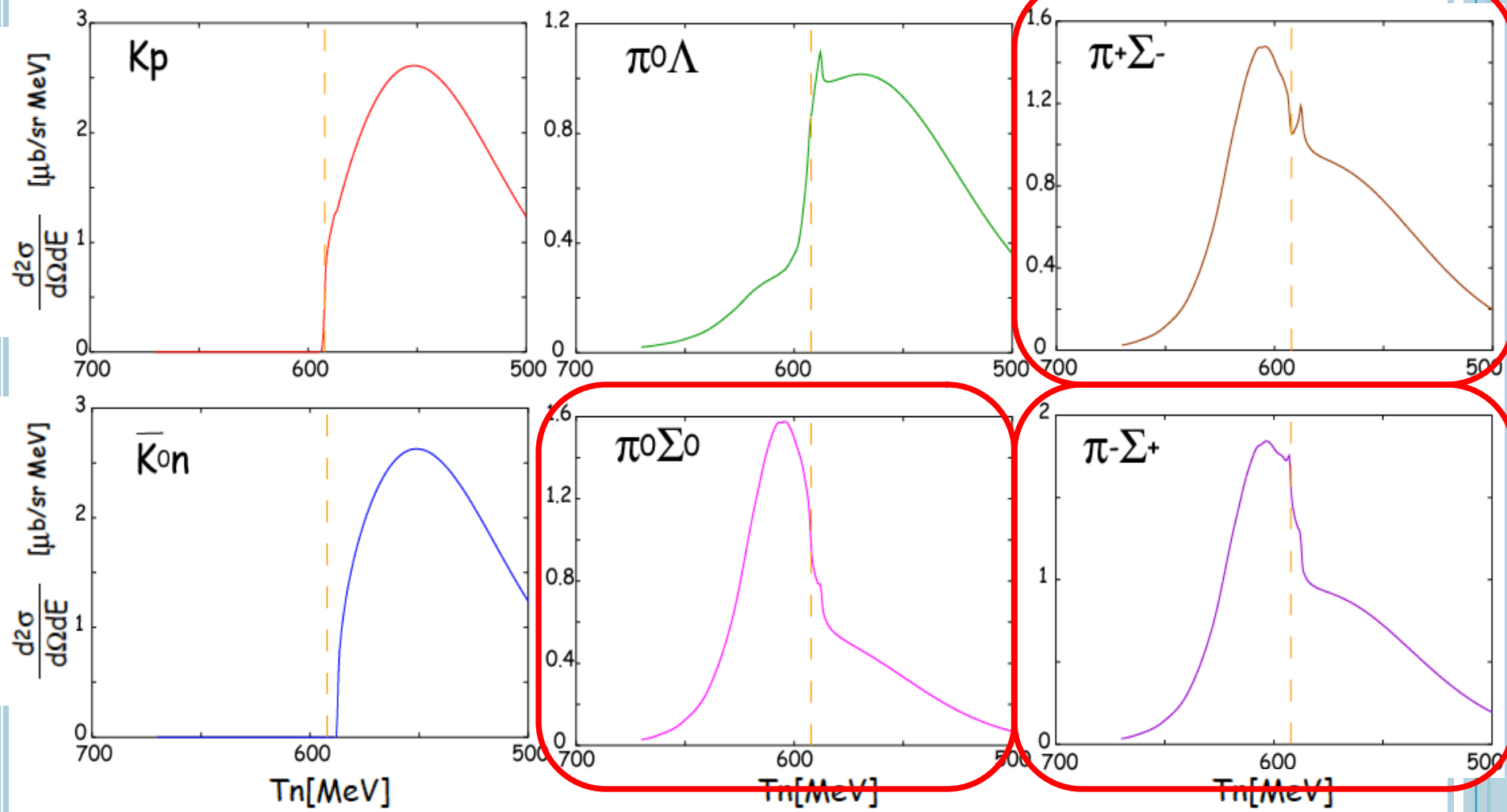
1-4. Results -- Conversion Part

^{3}He (K^-,n)

K^-pp

not include the contribution from $\Sigma(1385)$

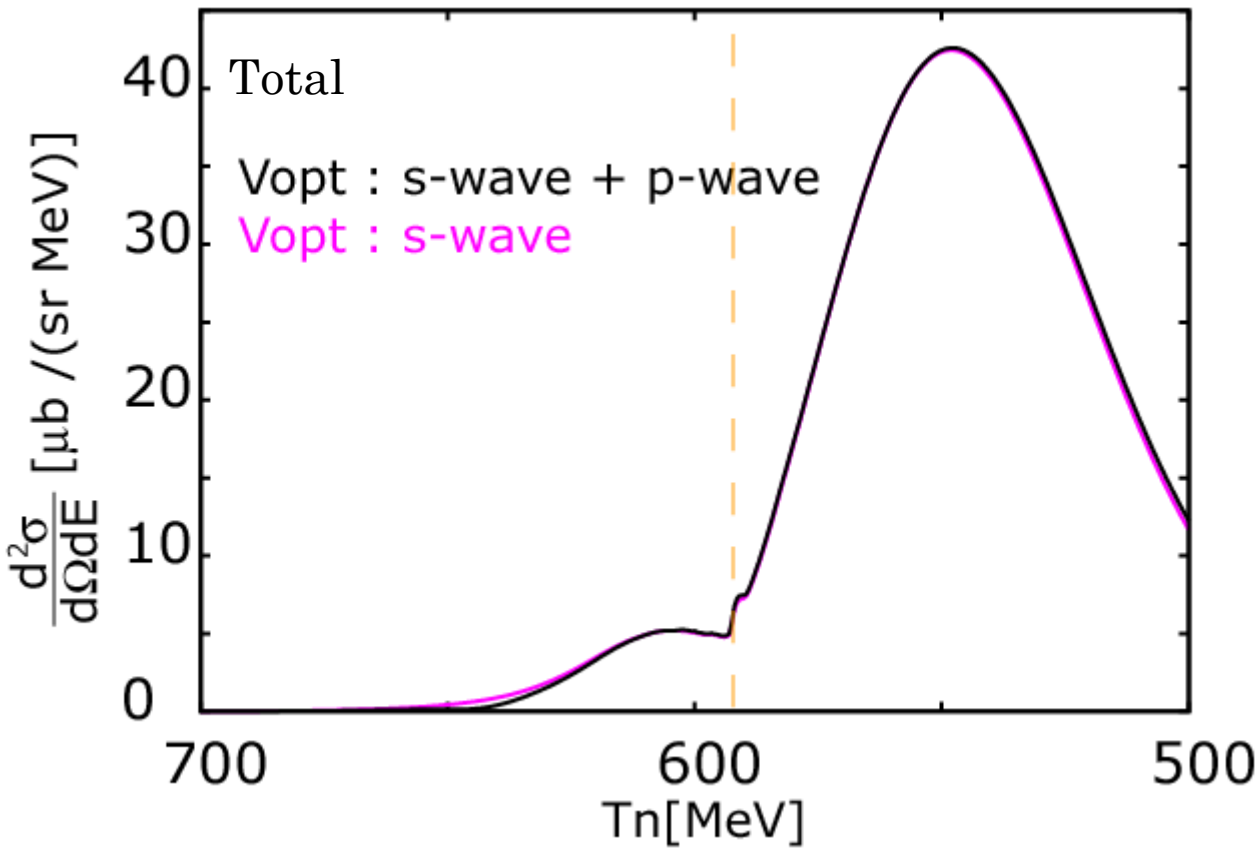
Dominant in bound region



1-4. Results – Σ(1385) resonance effects

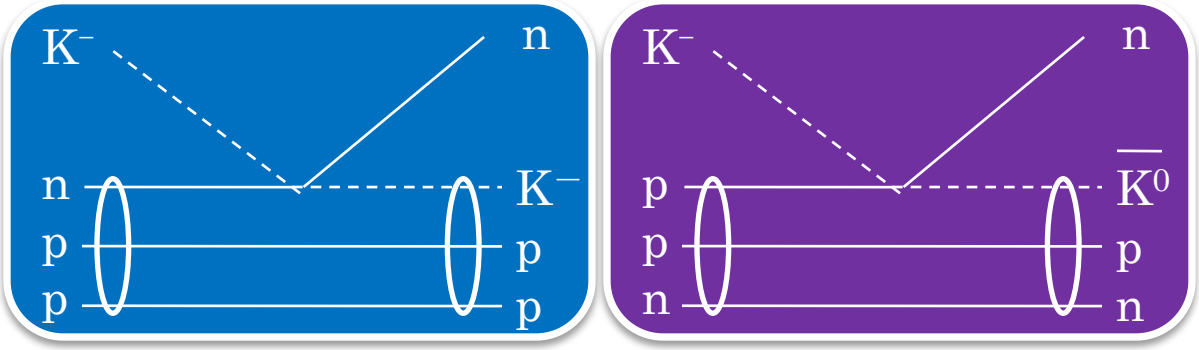
$$V_{\rm opt} = V_s(E,r) - \vec{\nabla}\cdot V_p(E,r)\vec{\nabla}$$

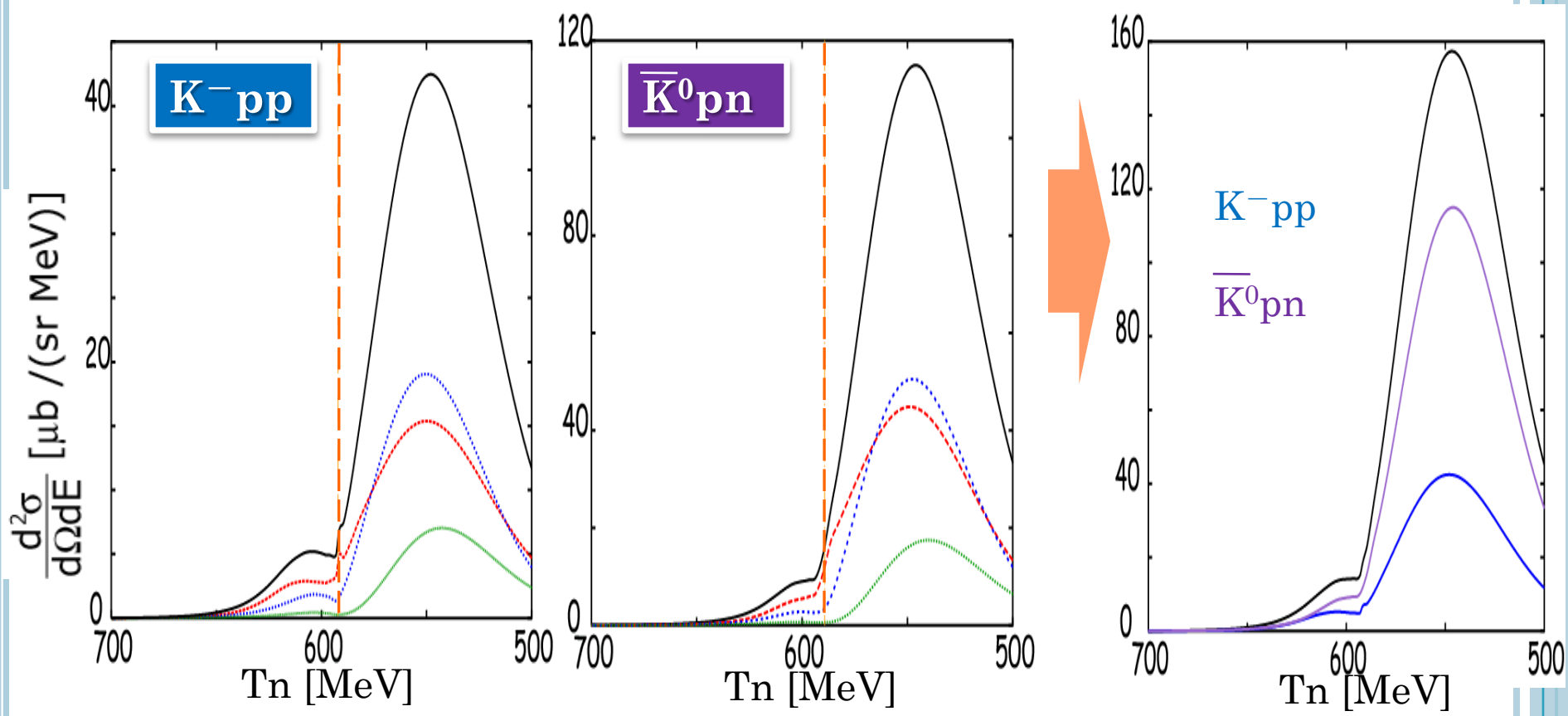
K^-pp



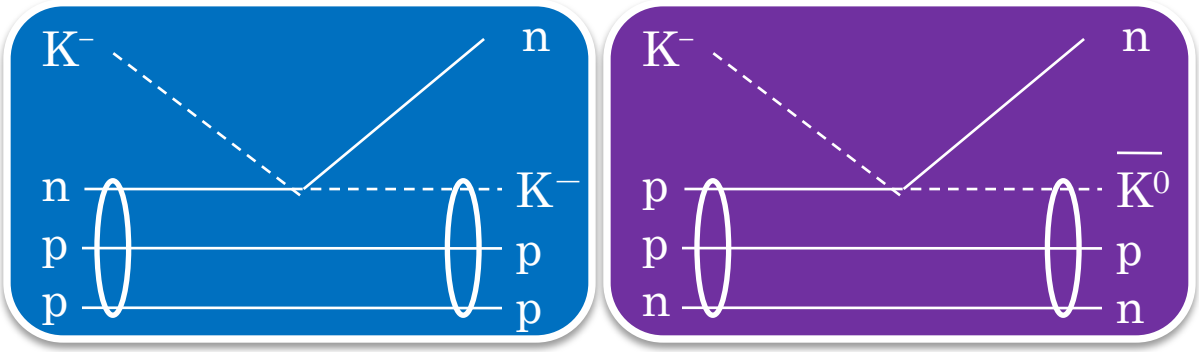
The contribution from Σ(1385) resonance effects seems to be small.

1-4. Results -- $^3He(K^-,n)$ -- possible final systems

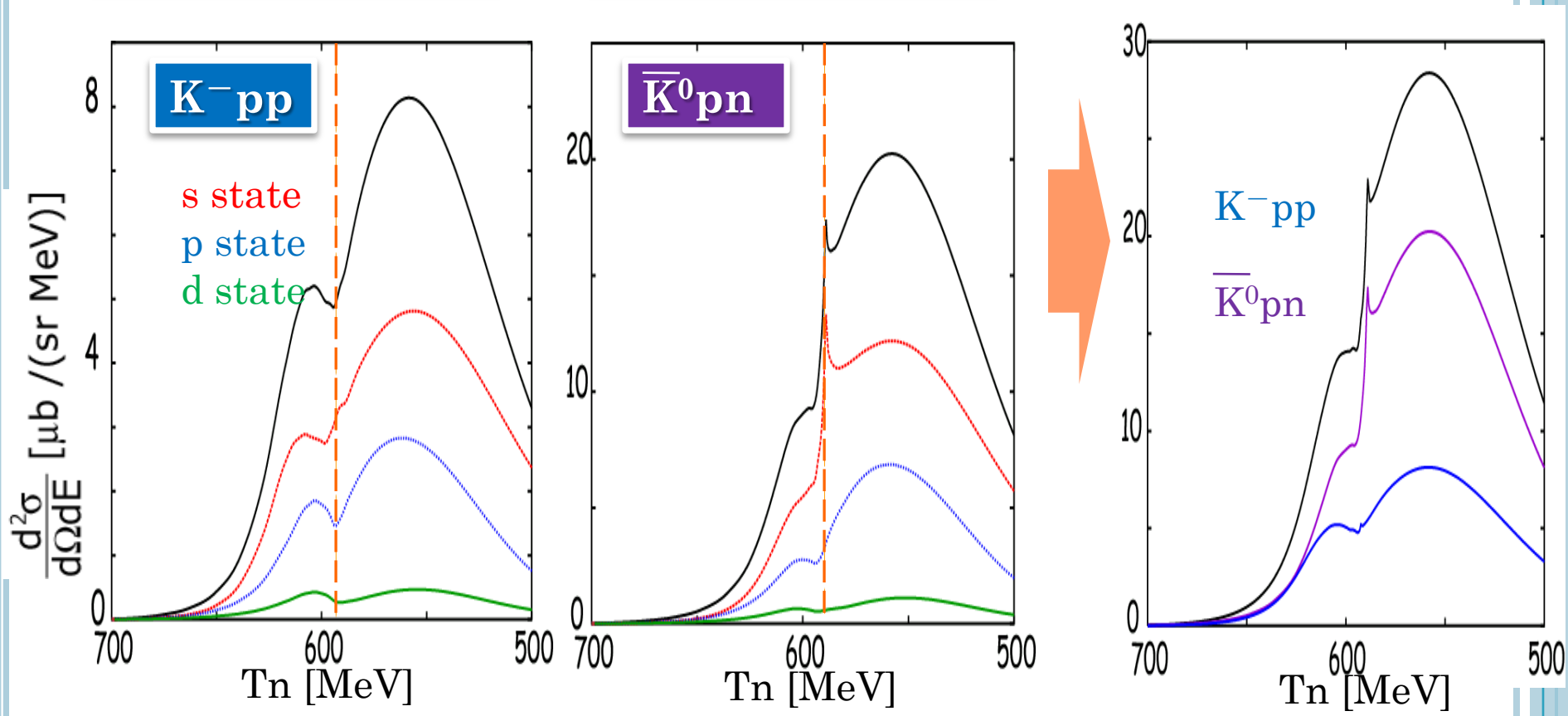




1-4. Results -- $^3He(K^-,n)$ -- possible final systems



Conversion part



1-5. Comments on our calculation for $\bar{K}NN$

- We don't calculate structure as few body systems.

  (Optical potential description by Tρ approximation for very light system)

- We assume density distribution of NN system.

  (improvements are required)

- We need to evaluate 2 body absorption correctly.
  - Chiral Unitary Model T(ρ=0,E) --- only 1 body absorption

1-6. Summary

- We calculated various $\bar{K}NN$ systems.

  -- Some bound states exist in complex E plane

  -- We may observe the small structures at bound region.

- We considered p-wave optical potential

  to take account of Σ(1385) resonance effects.

- We also considered $\bar{K}^0pn$ state in addition to K^-pp state

  in ^{3}He(K-,n) reaction.

- Σ(1385) resonance effects are small.
- Λ resonance effects are dominant in $\bar{K}NN$ formation spectra.

- We expect clearer signals in the conversion part.

  (Especially πΣ emission channels!!)