

E15 experiment in J-PARC

~Investigation of the light kaonic nuclei~

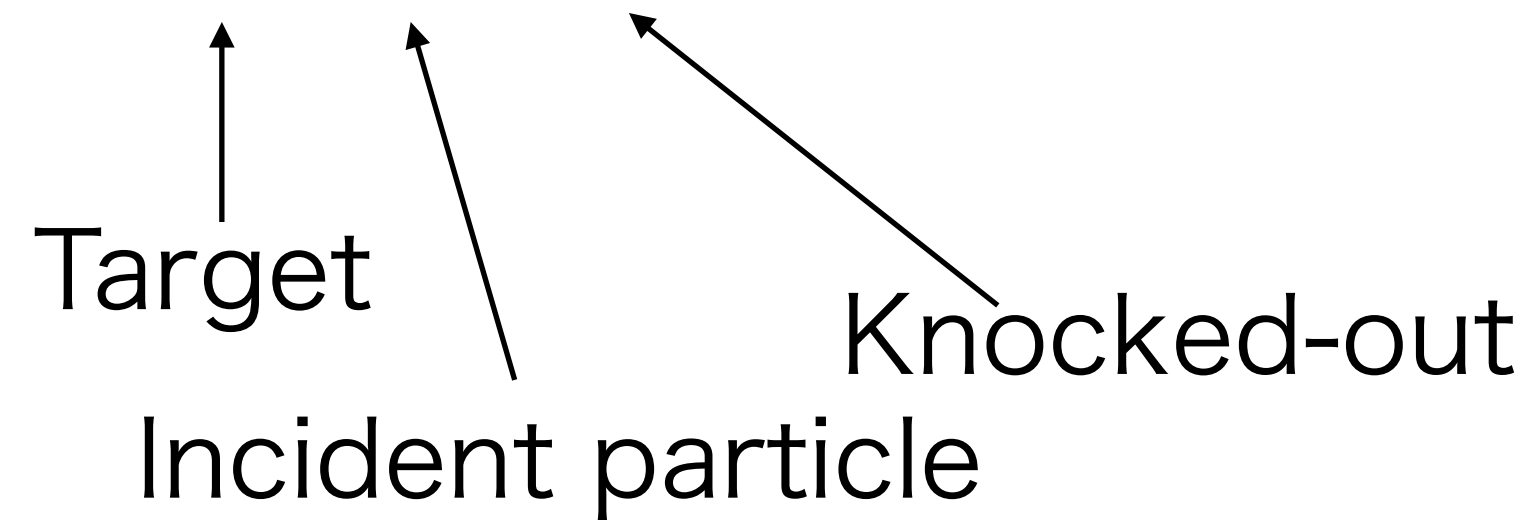
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1. Reactions

- The in-flight ${}^3\text{He}(K^-, N)$ reactions



- K^- consists of $\bar{u}s$, ${}^3\text{He}$ is composed of ppn .
- N is a nucleon. N は核子なので p or n

1. Reactions

- The kaon momentum of 1 GeV/c was used.

Why 1 GeV/c, not 400 MeV/c?

K^- の寿命とビームラインの長さを考慮すると、
400 MeV/cだとターゲットまで到達
 K^- が少なくなってしまう。だから1 GeV/cを選択。

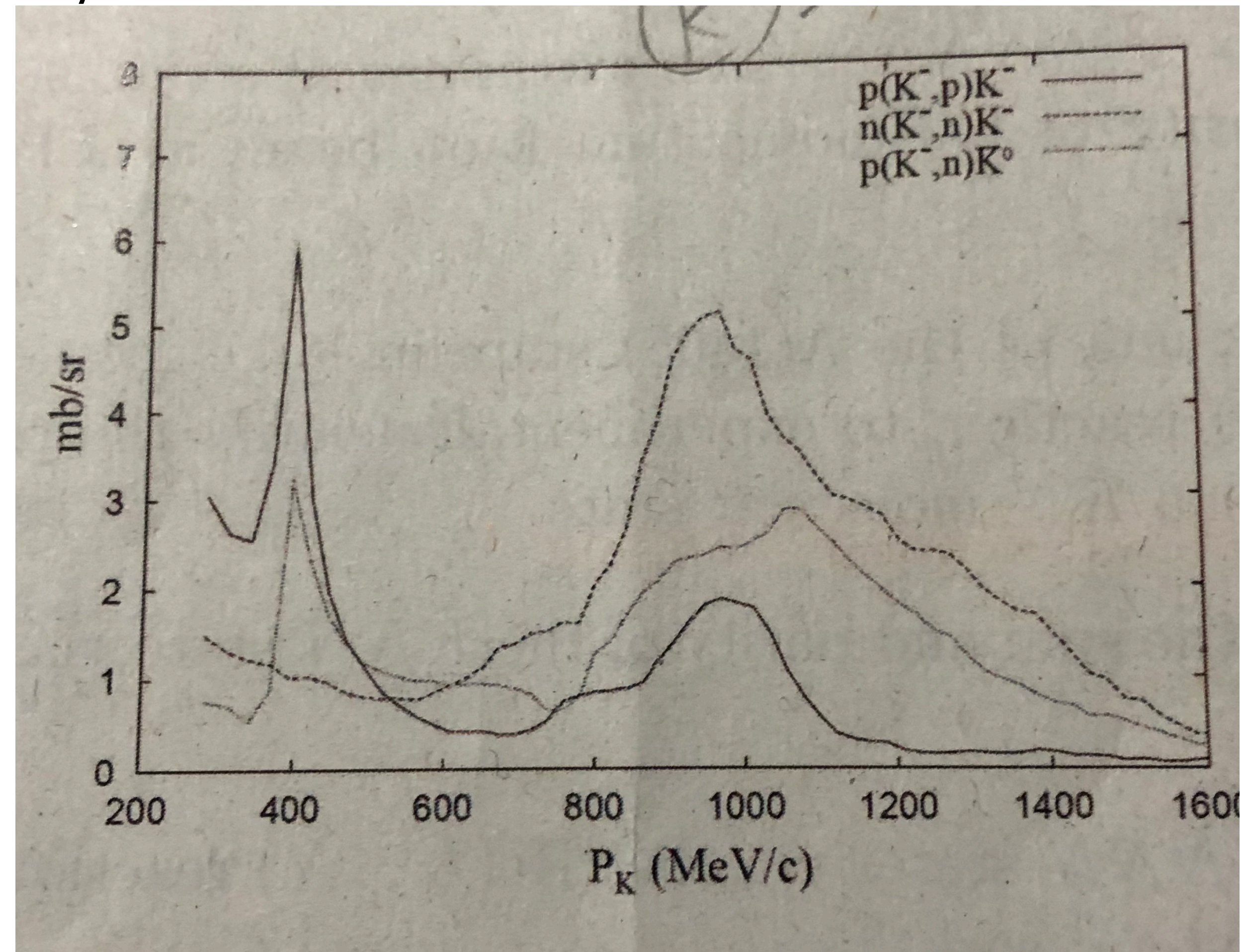


Figure 1: Cross section of the $KN \rightarrow KN$ reactions at $\theta_n = 0$ [0]

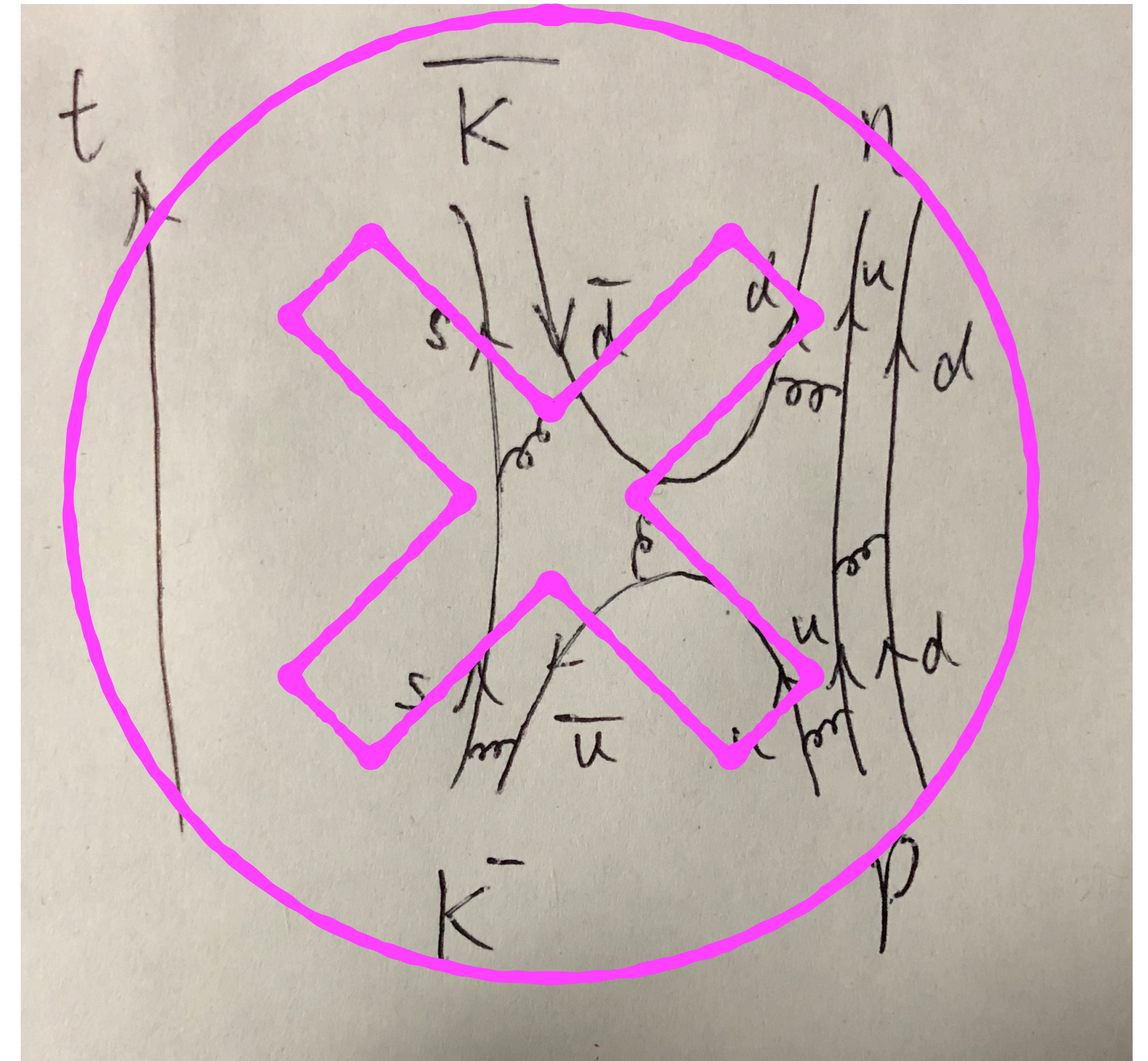
1. Reactions

- K^- has $\bar{u}$, p has u . In this case, K^- attracts p (p attracts K^-).

But n also has u , so does K^- attracts n doesn't it?

-Yes, it does. There are other reactions, for example, $n(K^-, n)K^-$.

- As a result, $\bar{K}$ and n are generated.
- This n is knocked out.
- Here, $\bar{K}$ behaves as 'off-shell' particle.
(But this $\bar{K}$ is almost real particle.)



この図は間違い

‘The momentum transfer q is defined between the incident kaon and the outgoing neutron in the laboratory frame $q = |\vec{p}_K^{lab} - \vec{p}_n^{lab}|$. In the reaction, we utilize this low-momentum back-scattered kaon as a ‘off-shell kaon’ source and residual spectator nucleons NN as an ‘actual target’ to form a “ K^-pp ” state, whose energy is below their intrinsic mass of $M(K^-pp)(=m_K + 2m_N = 2.37\text{GeV}/c^2)$.’

Systematic investigation of the light conic nuclei

-via the in-flight $4\text{He}(K^-, N)$ reactions-

より

1. Reactions

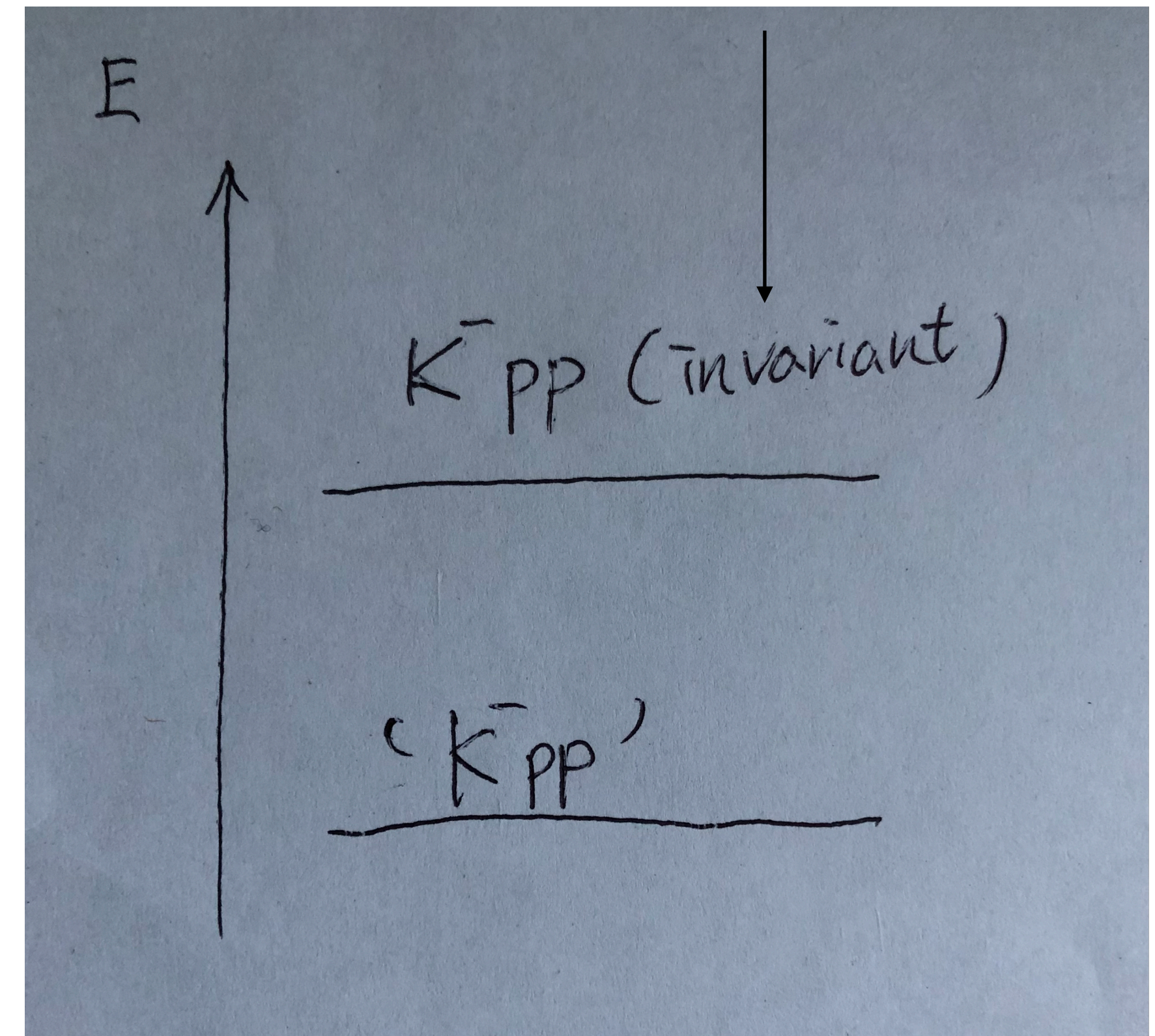
• $\bar{K} + pn \rightarrow 'K^-pp'$ ($\leftarrow$ kaonic nuclei)

$K^- + pp \rightarrow ?, K^- + pn \rightarrow ?$

• $'K^-pp'$ bound state is formed.

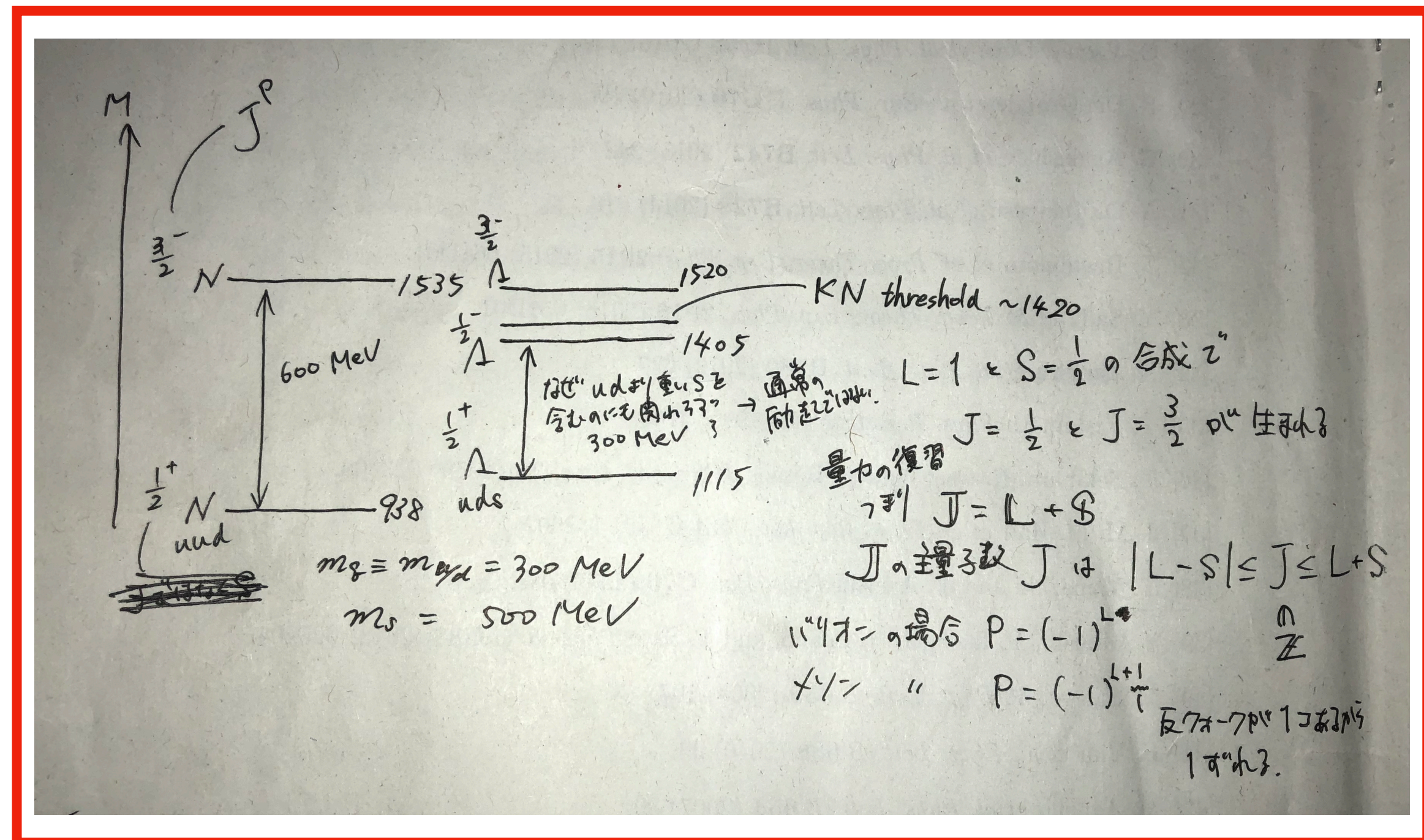
3つの状態いずれも $\bar{K}NN$ の状態です。

Invariantと書くのはおかしいです。
書くならばthresholdです。



2. Mystery of $\Lambda(1405)$

- Ground state Λ ($= 1115\text{MeV}$, $I = 0$, $J^P = \frac{1}{2}^+$) consists of uds .
- For a simple uds first excited state, the mass should be larger than 1405 MeV .



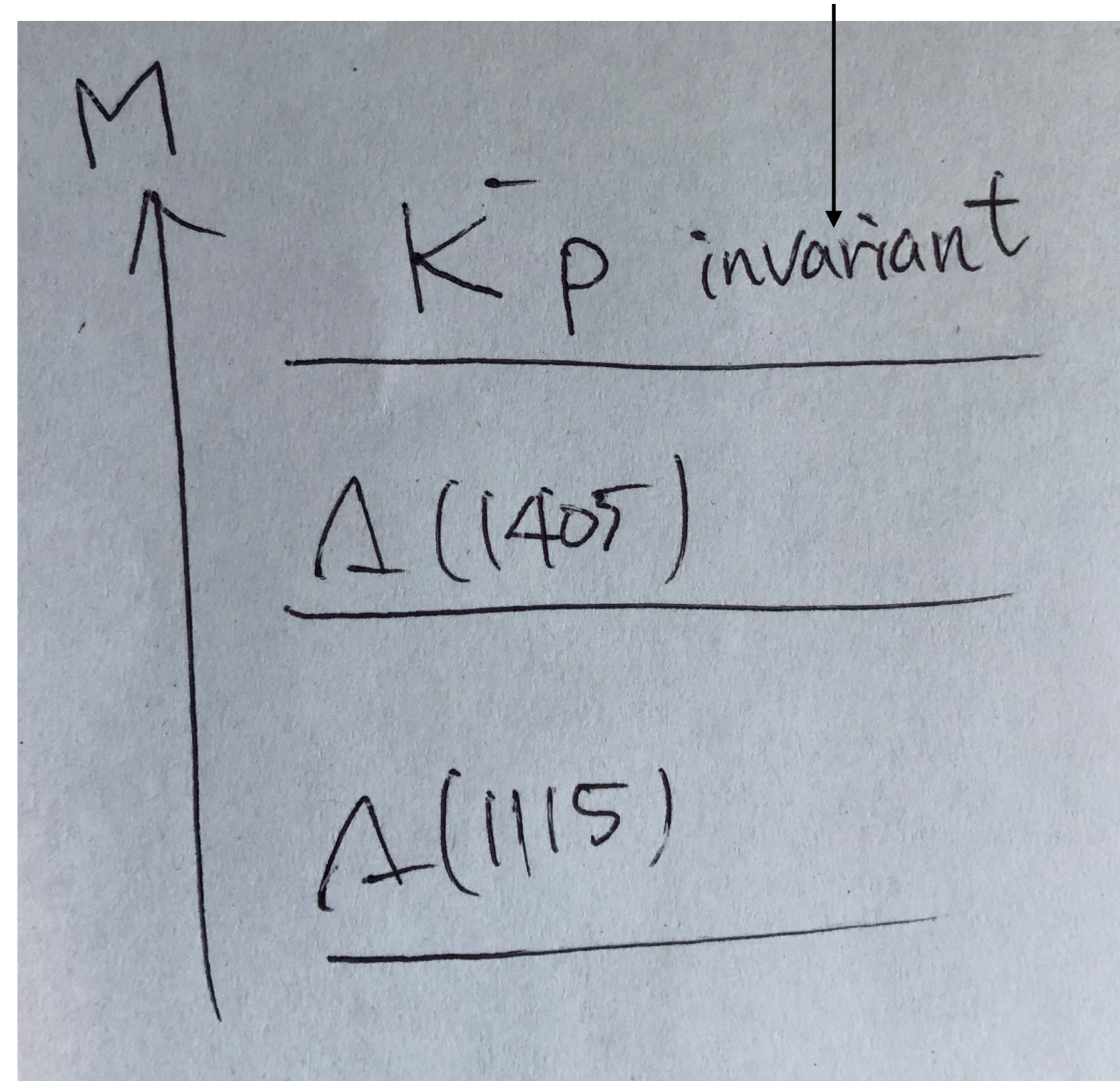
2. Mystery of $\Lambda(1405)$

- $\Lambda(1405)$ is ' K^-p ' bound state?

In the same way, ' K^-pp ' is $\Lambda(1405)p$?

Anyway, ' K^-pp ' and $\Lambda(1405)$ are related.

書くならinvariantではなくthreshold



2. Mystery of $\Lambda(1405)$

- Decay of $\Lambda(1405)$

$\Lambda(1405) \rightarrow \pi^\pm \Sigma^\mp$ is known.

↑
Strong interaction (I_3 is conserved.)

Clearly, $\Lambda(1405)$ is dominant.

This cross section is $\sim 200 \mu\text{b}$.

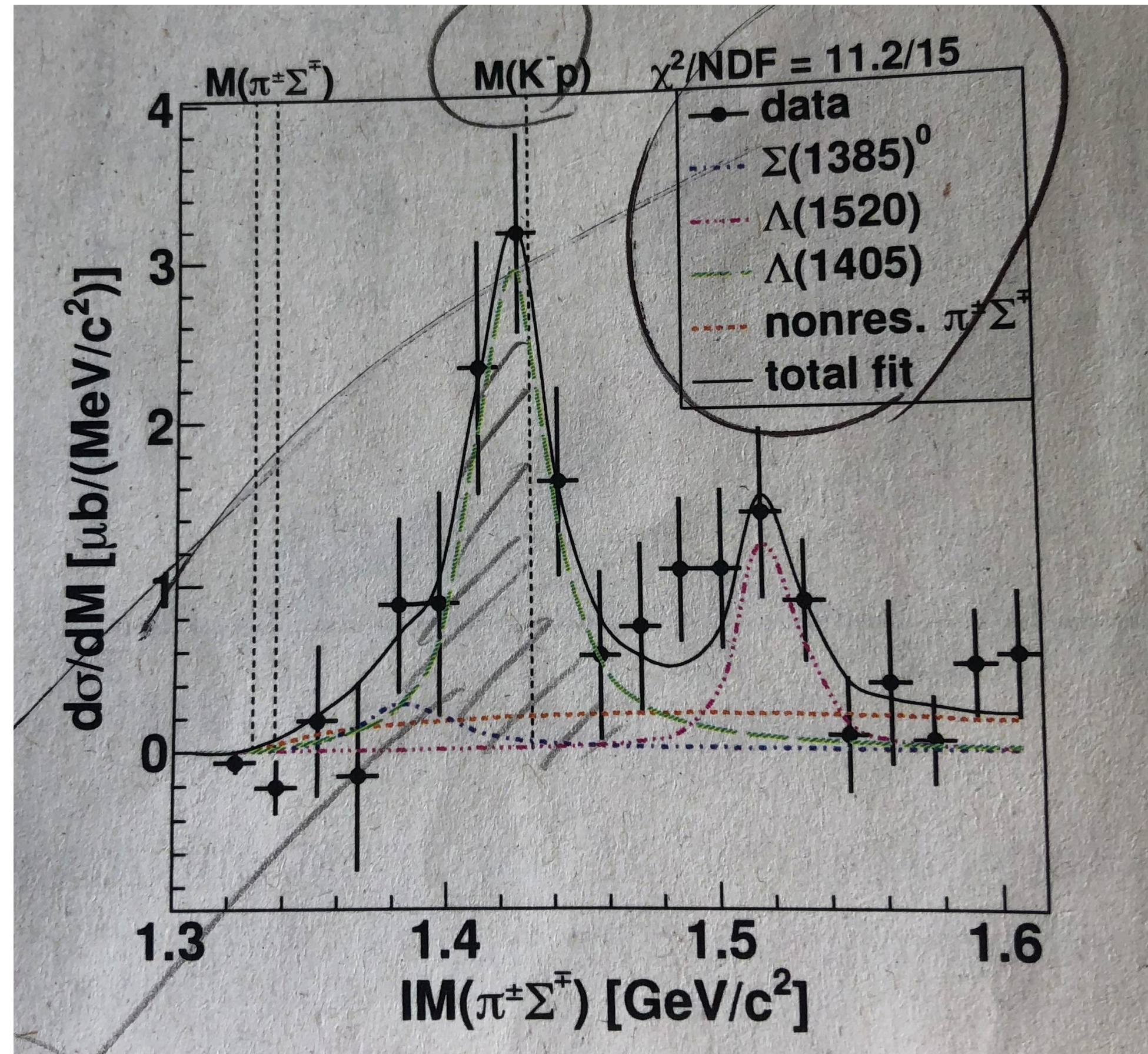


Figure 2: Efficiency and acceptance depending on parent particles of decay with final state $\pi\Sigma$. [0]

3. Results of E15

- To cut to the chase,

$$K^- + {}^3\text{He} \rightarrow Y^{*0} + p + n \text{ (This is final state.)}$$

- And then, Y^{*0} can be $\pi^\pm \Sigma^\mp$, $\Lambda(1115)$ (*i.e.* normal Λ) and Σ^0 .

Besides, Σ^0 decays into $\gamma\Lambda$.

So there are both mesonic and non-mesonic decay.

3. Results of E15

Both of them include bound state('K⁻p' and 'K⁻pp').

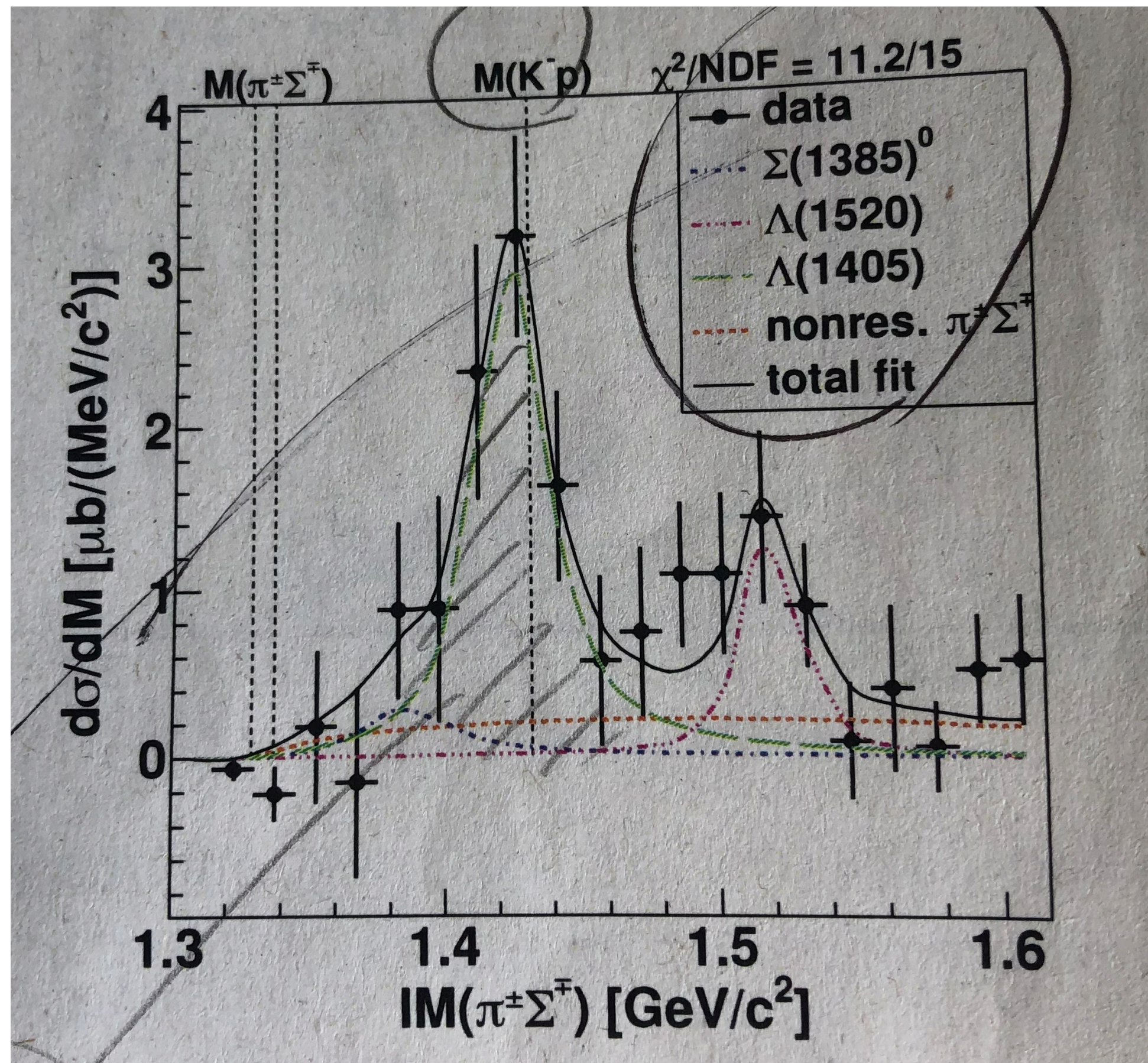


Figure 2 : again

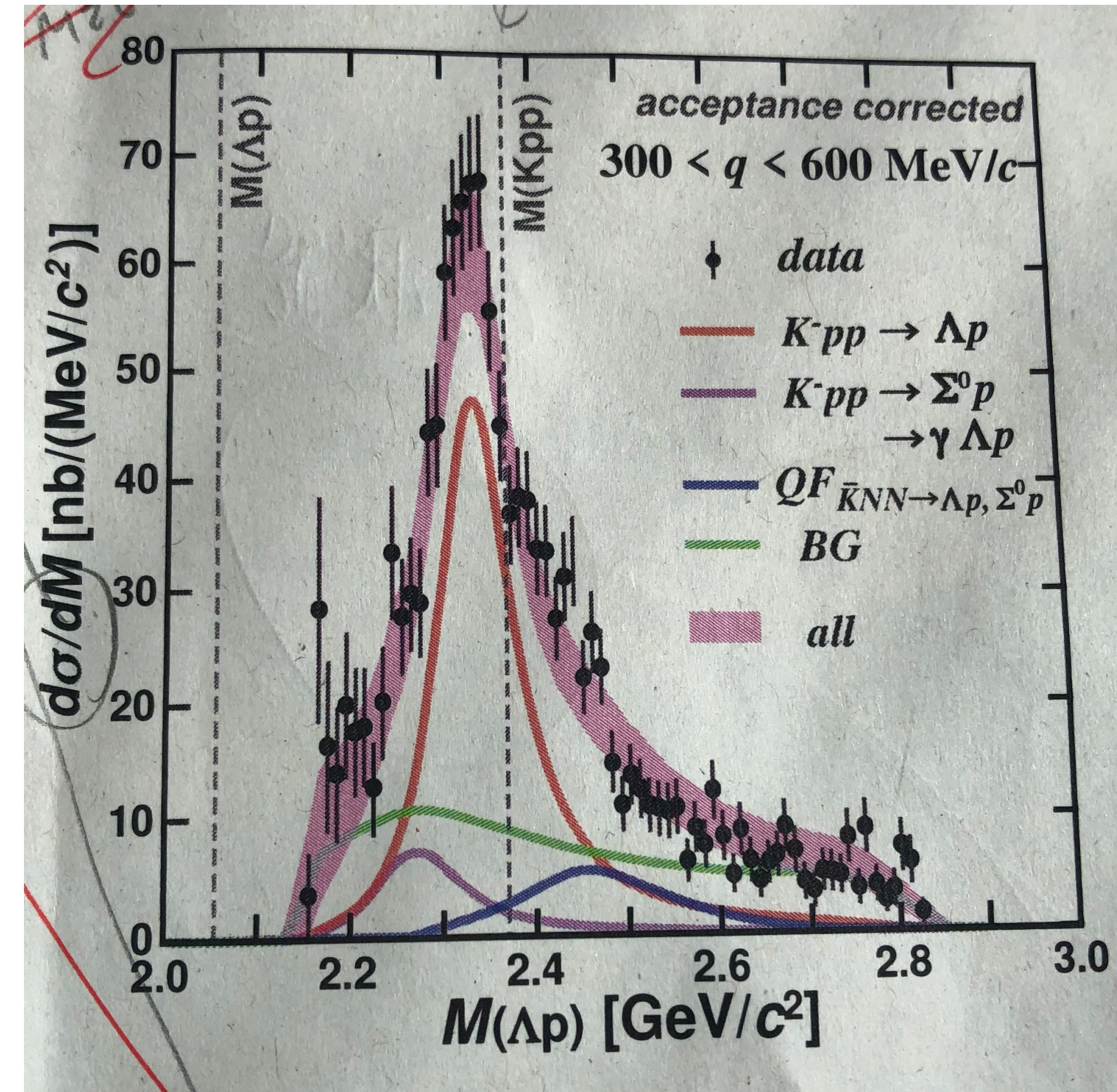


Figure 3 : Efficiency and acceptance corrected data over Λp invariant mass

3. Results of E15

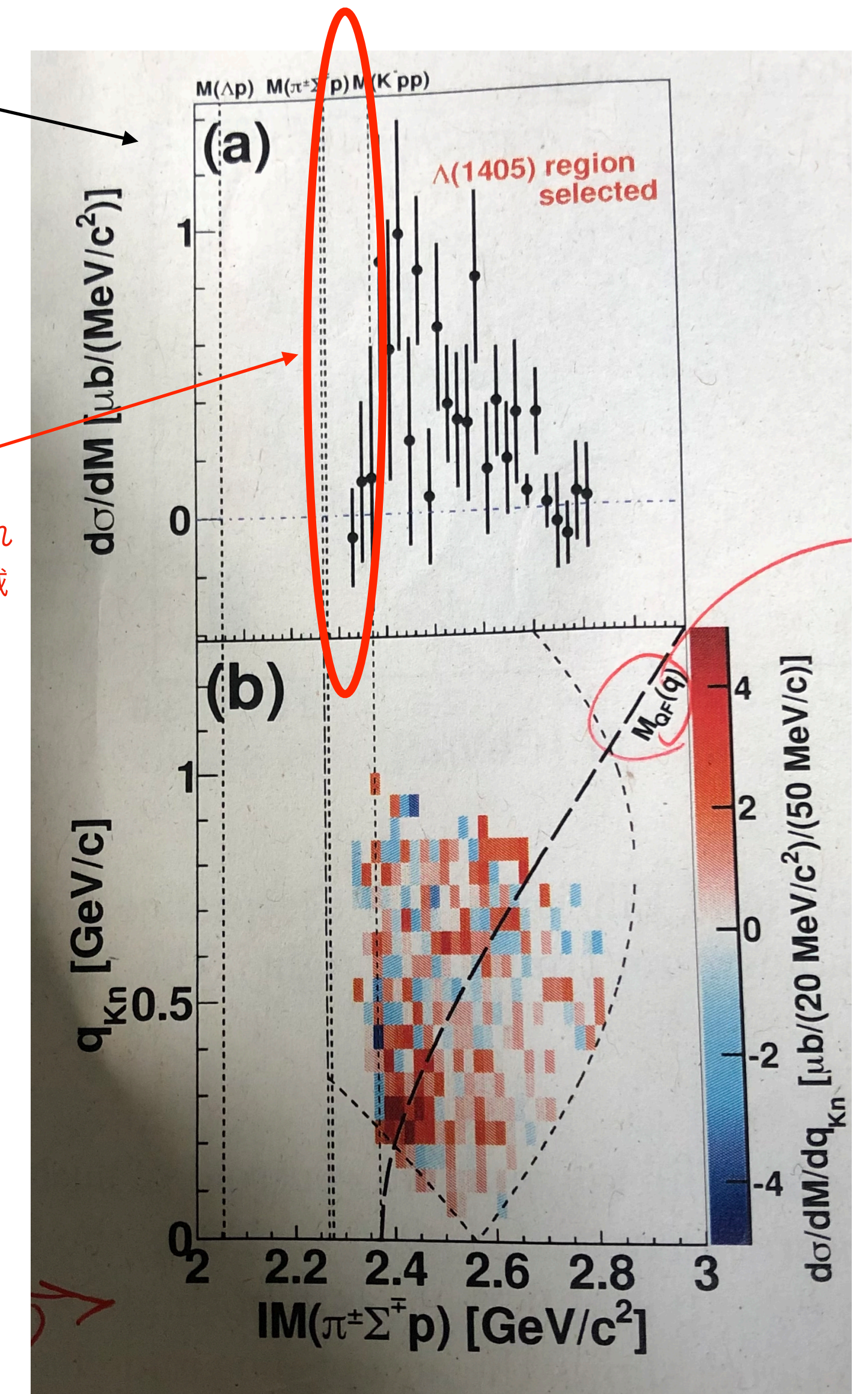
This data is selected from $\Lambda(1405)$ region in figure 2.

- In left figures, we can regard the final state as $\Lambda(1405) + p + n$. We can see that the $\Lambda(1405) + p + n$ event distribute above the $M(K^-pp)$ threshold.

1 核子吸収は8割
2 核子吸収は2割

過去のstopped Kaonの実験結果から、図2であれだけ(200ub) $\Lambda(1405)$ ができていますのでこの領域(束縛領域)にもっとデータがあると思っていた。理想的にはピークが立って欲しかった。仮にここにピークが隠れていなければ、束縛状態の描像として" $\Lambda(1405)p$ "は不適切となる。

In this case, it doesn't form ' K^-pp ' bound state. But ' K^-p ' bound state ($\Lambda(1405)$) is formed.



3. Results of E15

- Therefore, the non-mesonic decay is dominant when the ' K^-pp ' bound state is formed.

”One may integrate over the phase space to obtain the total decay rate for the specified final state.”

https://en.wikipedia.org/wiki/Particle_decay

以下のように崩壊位相空間を考慮すれば一応一貫した説明ができるがそれが本質かどうかはわからない。E15実験では統計的に不満足な点が主に2点あった。1つは中性子のmissing massがneutron detectorが3cmしかないため、3%しか解析できなかったこと。2つめは図3のpi-sigma-pのthreshold付近が重要なのに関わらず、edgeなために十分なacceptanceが得られず、さらに統計的取り扱いが難しいこと。

That is because of the decay phase space. The $\pi\Sigma N$ -decay phase space below $M(Kpp)$ threshold is kinematically limited in the $\pi\Sigma$ decay ($\sim 100\text{MeV}/c^2$) (Figure 2), while the Λp -decay phase space has no limitation reaching to $\sim 300\text{MeV}/c^2$ below $M(Kpp)$ (Figure 3).

3. Results of E15

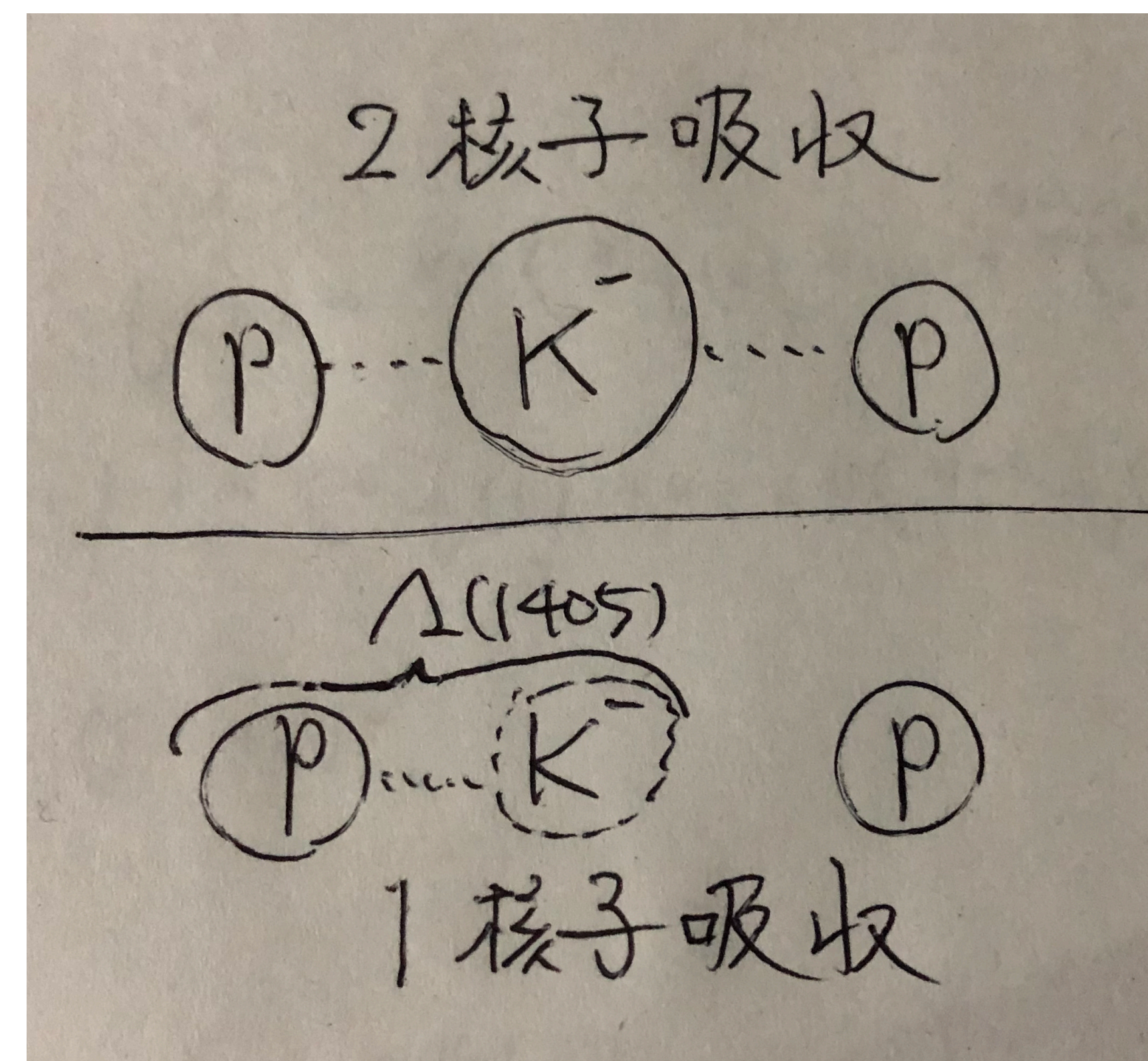
- " K^-pp " bound state $\neq \Lambda(1405)p$

Kが束縛状態を作るため（波動関数を残りの核子に重ねる（位相空間を近づける））に余分なエネルギーを2つある核子のうちの1つに与えています。

When the kaon energy is below the intrinsic mass ($E_K^{lab} < m_K$), the recoiled kaon ' $\bar{K}$ ' is captured by two residual nucleons. And then, the bound state " K^-pp " is produced.

$E_K^{lab} < m_K$ と言っている時点で暗にKは束縛されていると言っているようなものなので、
この文章はあまり意味がありません

When the scattered-kaon energy is above its intrinsic mass ($E_K^{lab} > m_K$), ' $\bar{K}$ ' knocks out a residual proton due to its excess energy, and the kaon is successively absorbed in the other residual nucleon as 'off-shell kaon'. This results the $\Lambda(1405)$ (" K^-p " bound state).



4. Next plan

5. My Q.

- In p.8 Figure 3, why does the peak of bound state exceed the mass threshold?
- "Quasi-free" means "not bound" ?
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