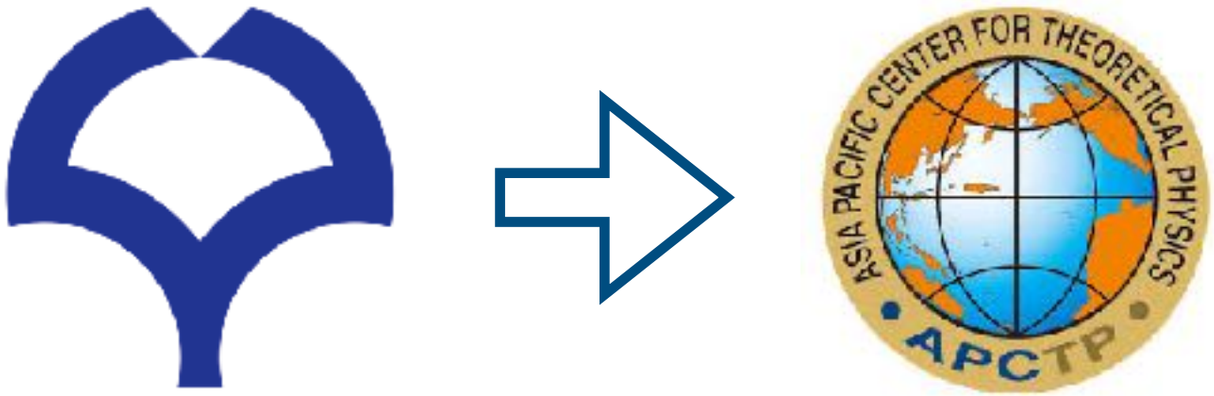
Two-pion emission decay of Roper-like heavy baryons



Ahmad Jafar Arifi

(H. Nagahiro, K. Tanida & A. Hosaka)

「量子クラスターで読み解く物質の階層構造」スクール

March, 2021

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こんにちは！
안녕 하세요!

Roper puzzle (1963): almost 60 y.o.

PDG

$N(1440)$: ****

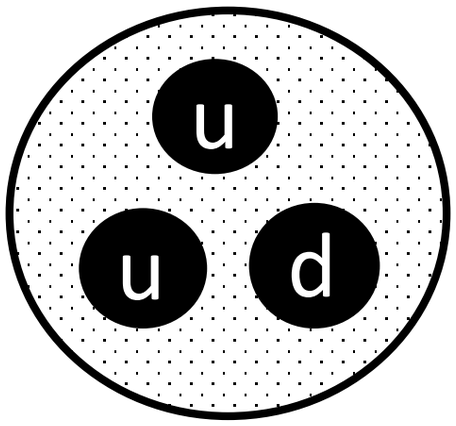
$N^* \to N\pi$ 55-75%

$N^* \to N\pi\pi$ 17-50%

$M = 1440$ MeV

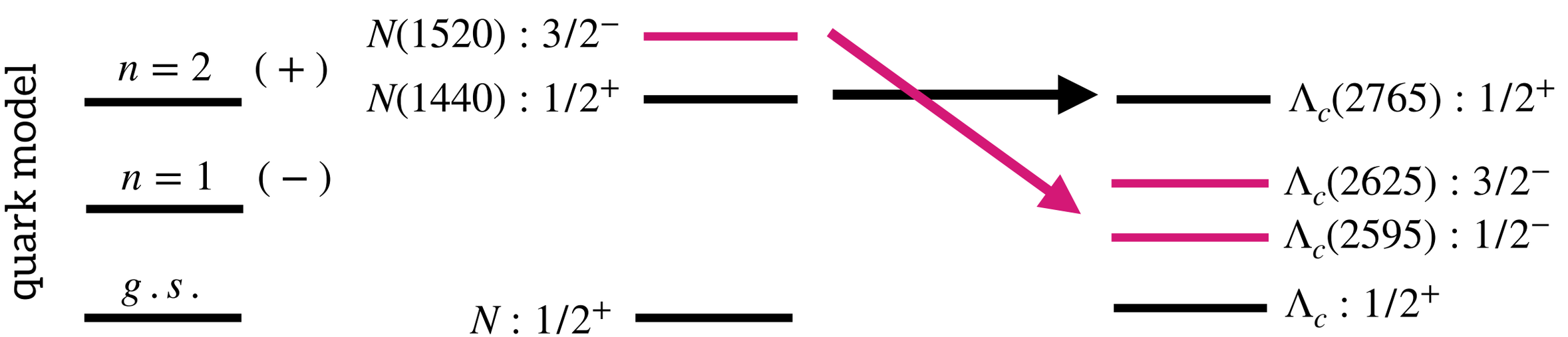
$\Gamma = 350$ MeV

$J^P = 1/2^+$



Not compatible with the quark model:

Mass, level ordering, decay property

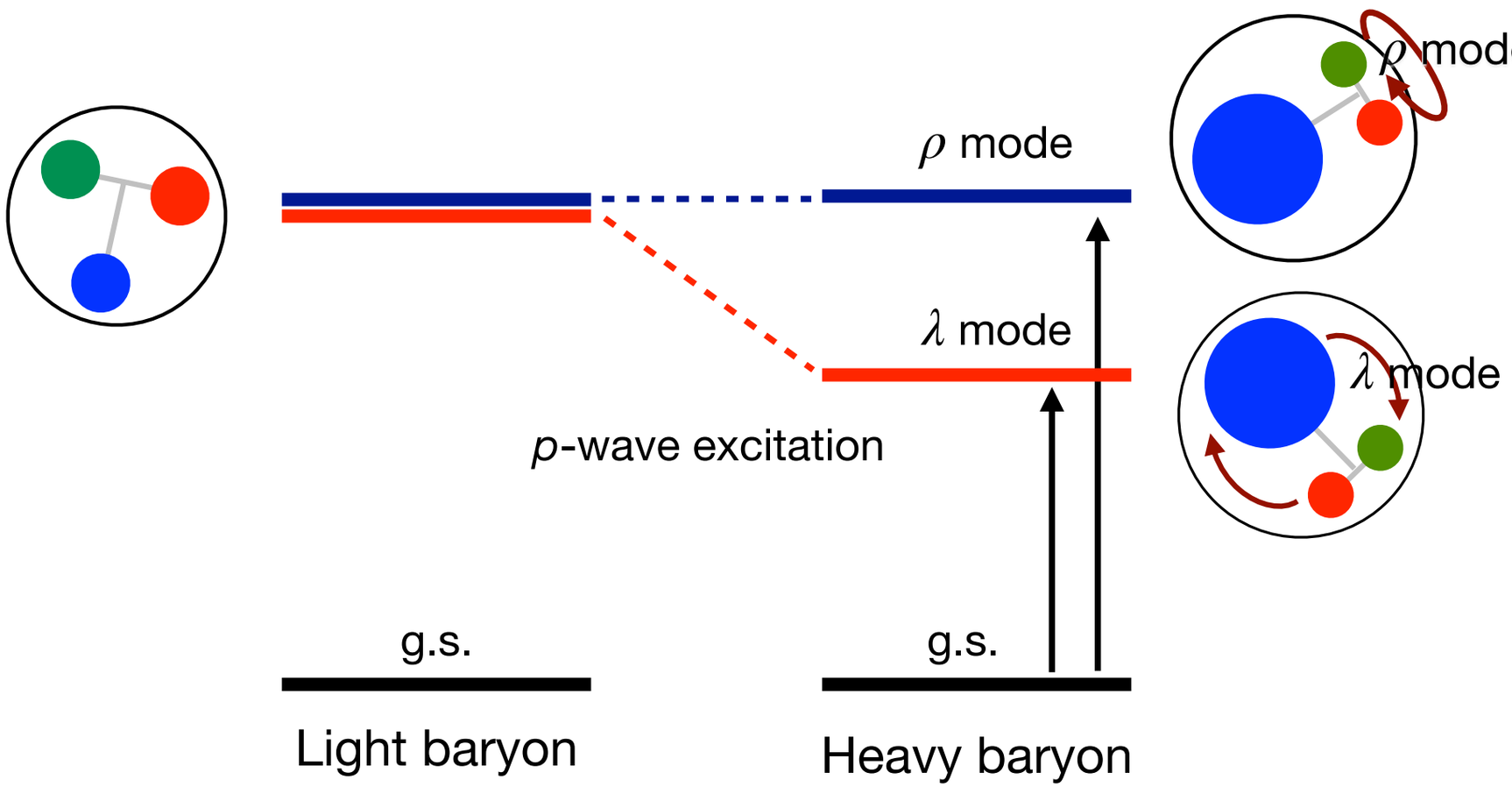


Burkert & Robert, Rev Mod 91, 011003 (2019).

Light and Heavy baryons

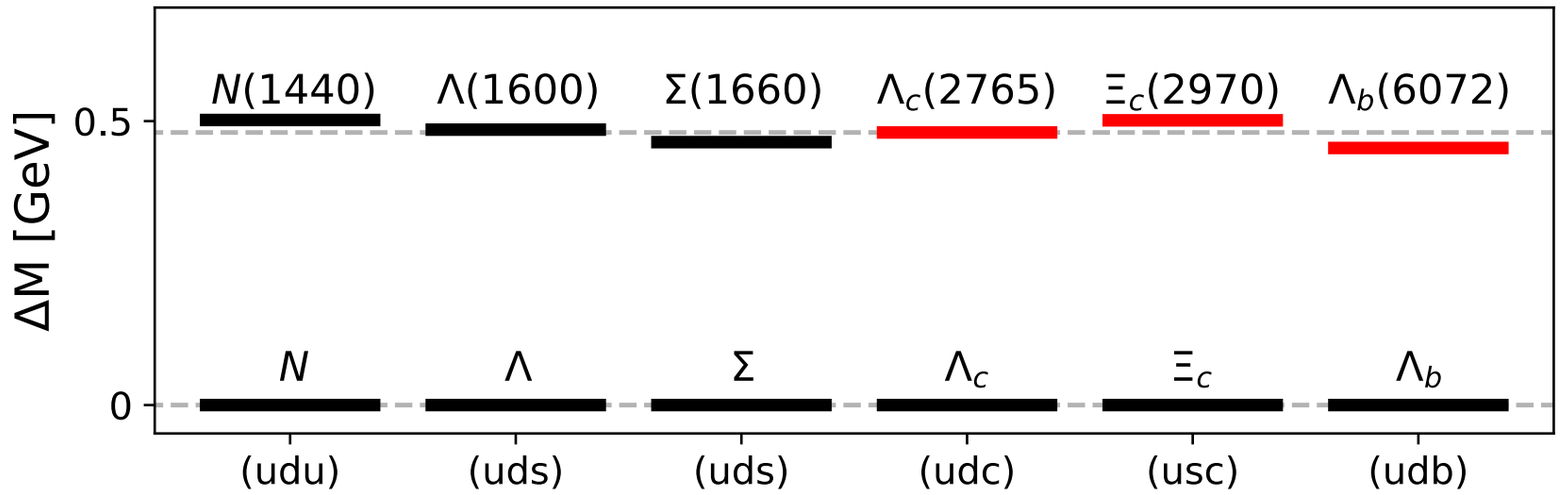
light | u d s | c b | heavy

- Heavy quark symmetry
- Isotope shift



Lowering the λ-mode excitation.

Roper-like heavy baryons



PDG		
	$\Lambda_c(2765)$: *	$M = 2765$ MeV $\Gamma \sim 50$ MeV
	$\Lambda_c \to \Lambda_c\pi\pi$	$J^P = ?$

- Not well established.
- Spin and parity are unknown

Not listed		
	$\Lambda_b(6072)$	$M = 6072$ MeV $\Gamma = 72$ MeV
	$\Lambda_b \to \Lambda_b\pi\pi$	$J^P = ?$

PDG		
	$\Xi_c(2970)$:***	$M(\Xi_c^+) = 2966$ MeV $\Gamma(\Xi_c^+) = 20.9$ MeV
	$\Xi_c \to \Xi_c\pi\pi$ $\Xi_c \to \Xi_c'\pi$, etc	$J^P = 1/2^+$

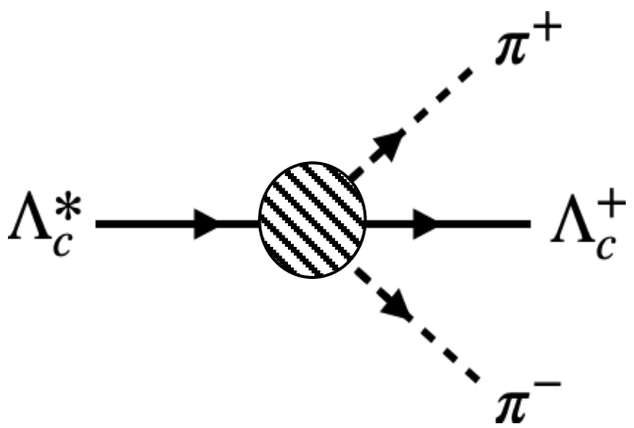
- Properties similar to $\Lambda_c(2765)$

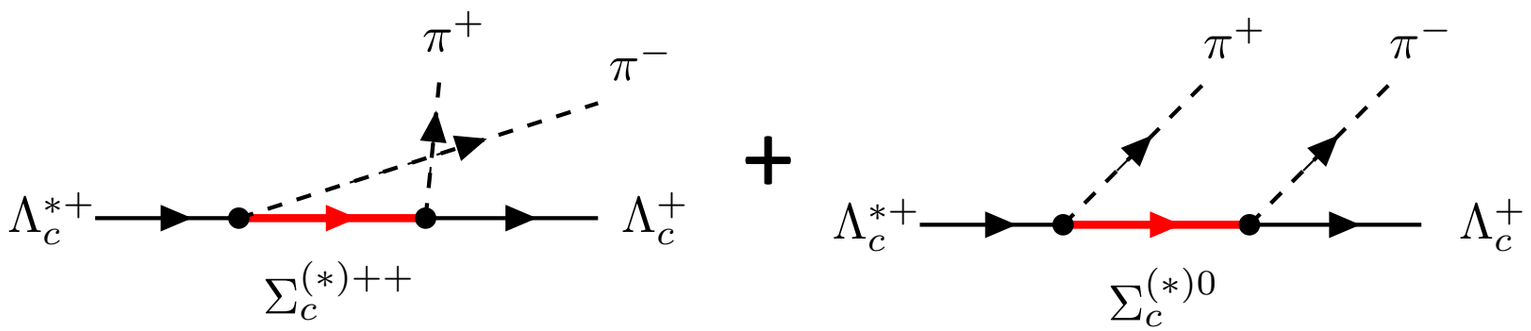
  LHCb, JHEP **06** 136 (2020)

- Its spin-parity is determined recently

  Belle, arXiv: 2007.14700

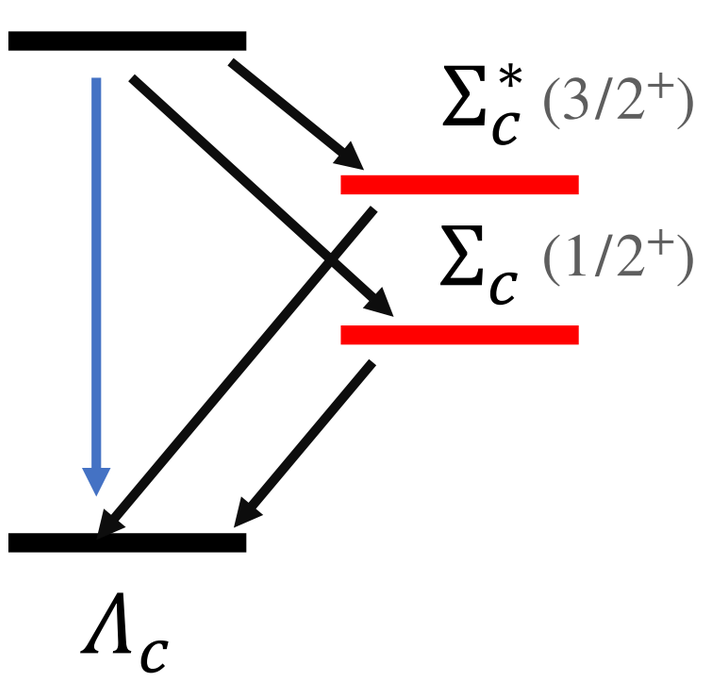
Spin-parity determination





Two-pion emission decay

$\Lambda_c(2765)$



- Sequential processes through $\Sigma_c^{(*)}$ states.
- The coupling strengths —> quark model.

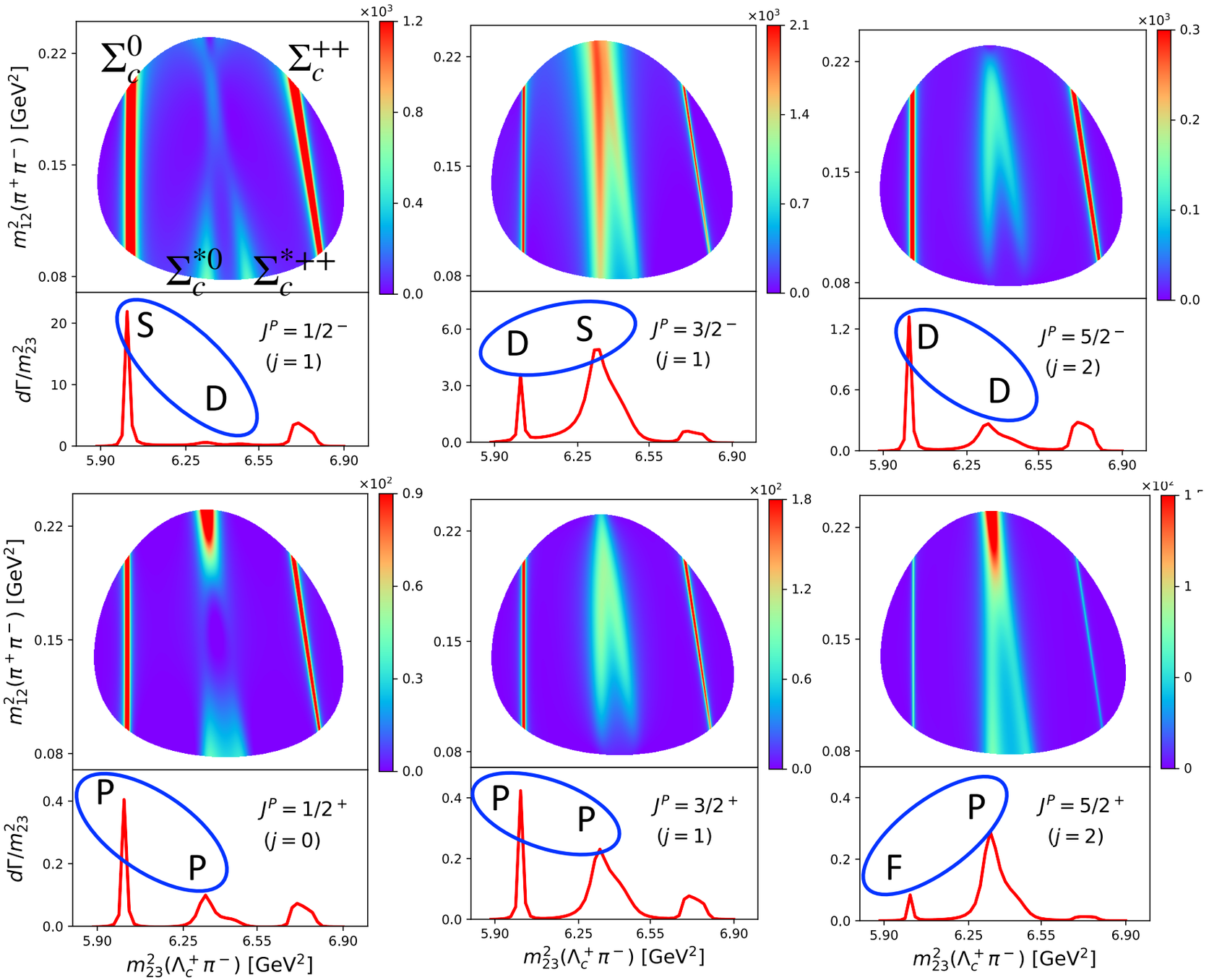
- (FAQ) Non-resonant process is negligible (implied from exp. observation).

$\Lambda_c(2595)$ and $\Lambda_c(2625)$

Arifi, *et. al.* PRD95 114018 (2017)

Arifi, *et. al.* PRD98 114007 (2018)

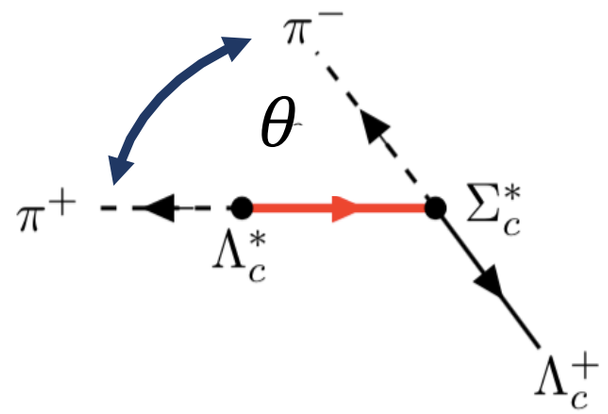
Dalitz plot: $\Lambda_c^*(2765)$ decay



Ratio

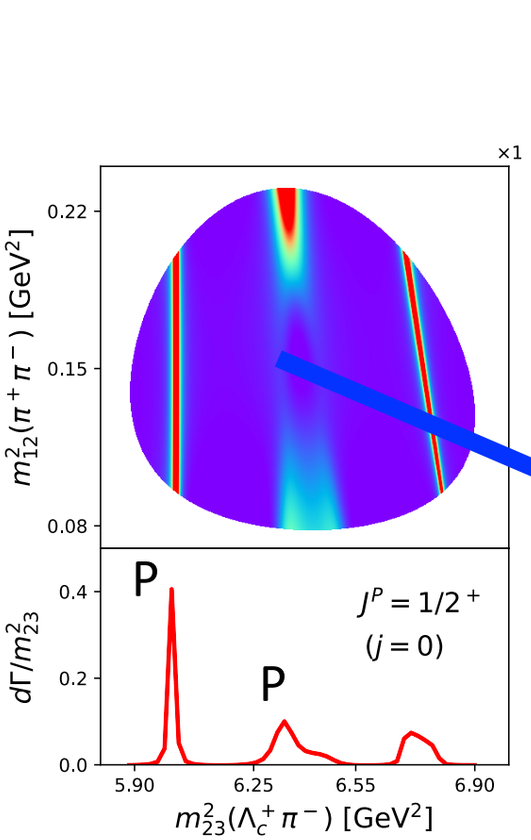
$$R = \frac{\Gamma(\Lambda_c^* \to \Sigma_c^* \pi)}{\Gamma(\Lambda_c^* \to \Sigma_c \pi)}$$

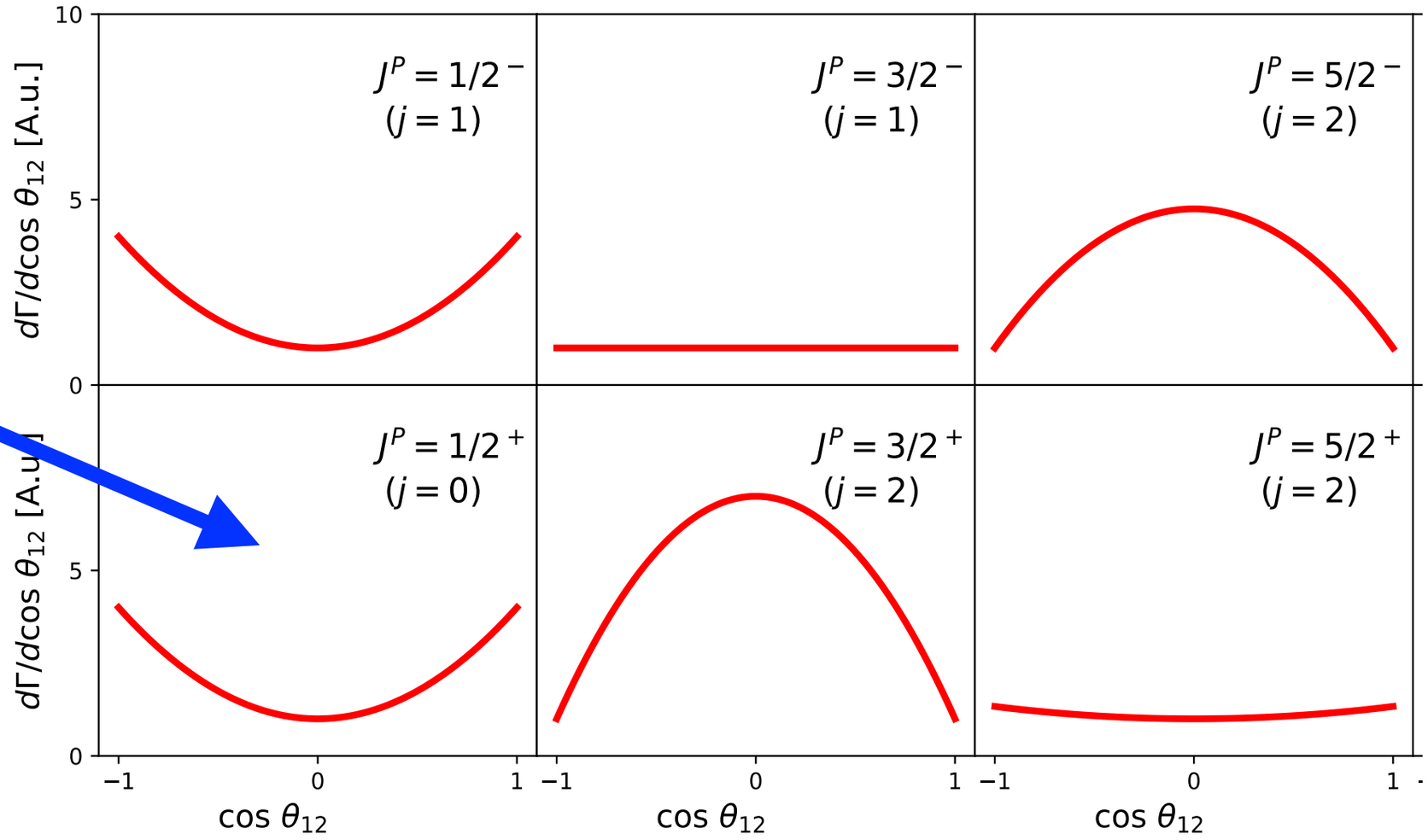
Angular correlation



Arifi, *et. al.* PRD101 094023 (2020)

Angular correlation: $\Sigma_c^*(3/2^+)$ band





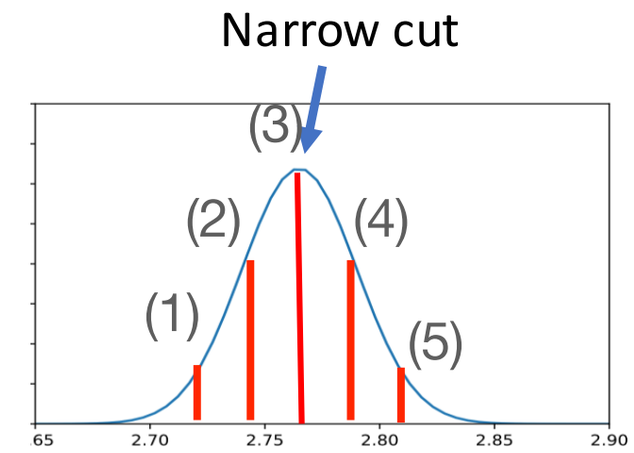
$$W(\theta) \propto |A_{1/2}|^2 (1 + 3\cos^2\theta) + |A_{3/2}|^2 3\sin^2\theta$$

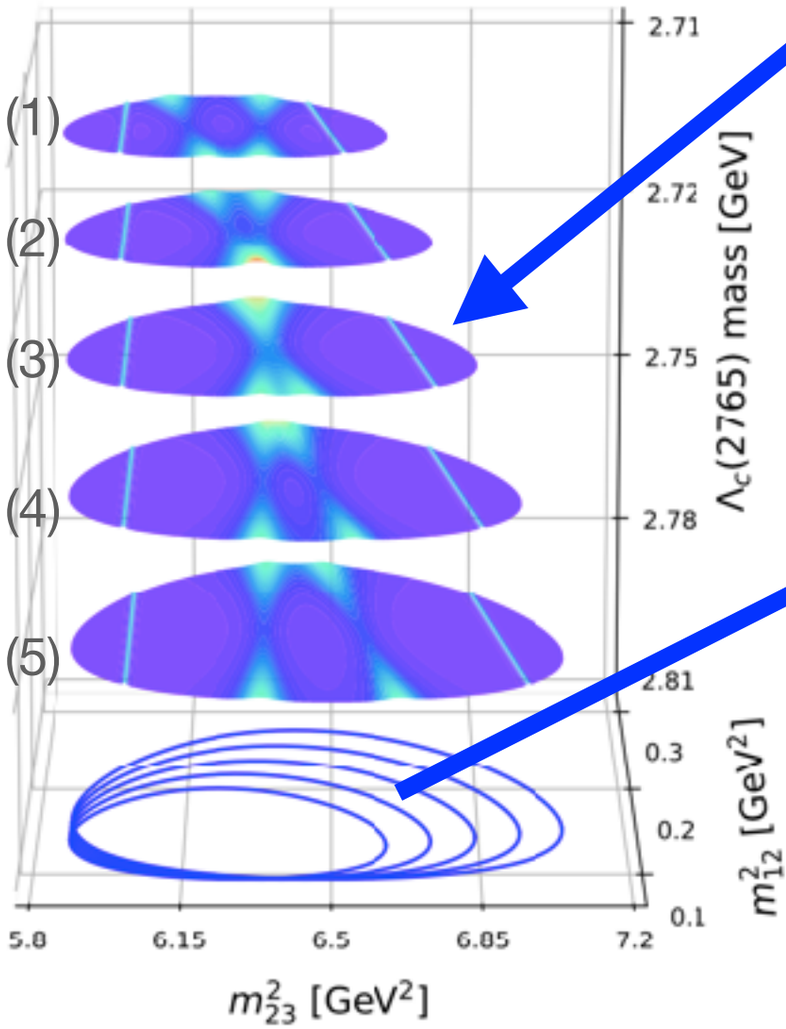
Valley Hill

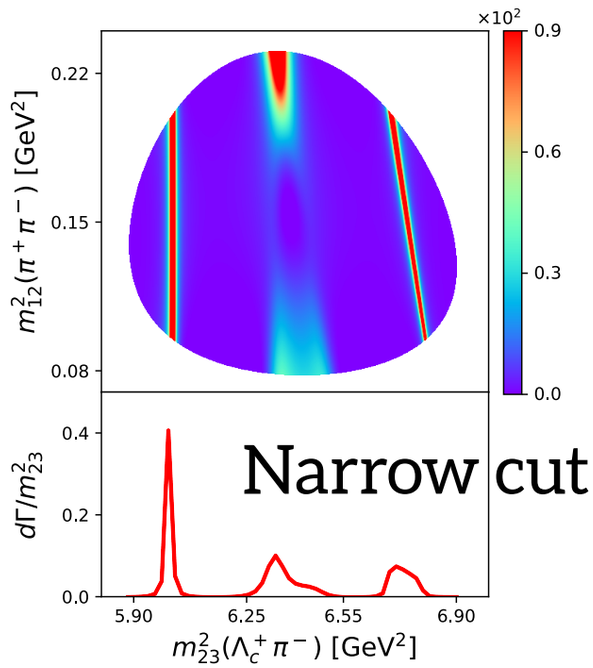
$$\tilde{R} = \frac{|A_{3/2}|^2}{|A_{1/2}|^2}$$

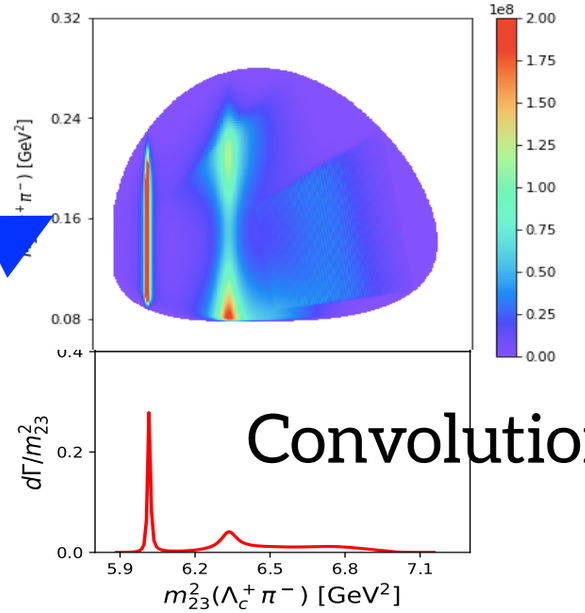
Arifi, *et. al.* PRD101 094023 (2020)

$\Lambda_c^*(2765)$ decay: Convolution

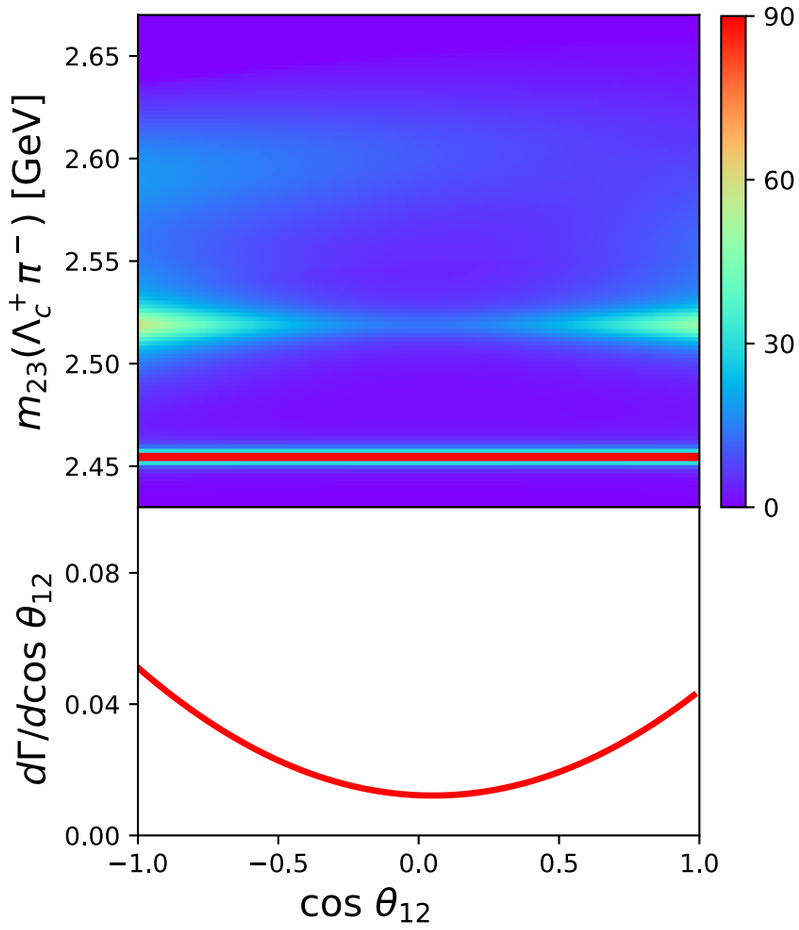








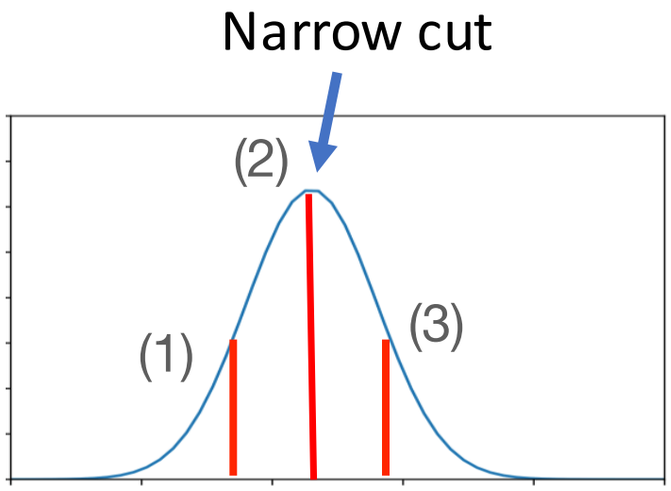
Convolution

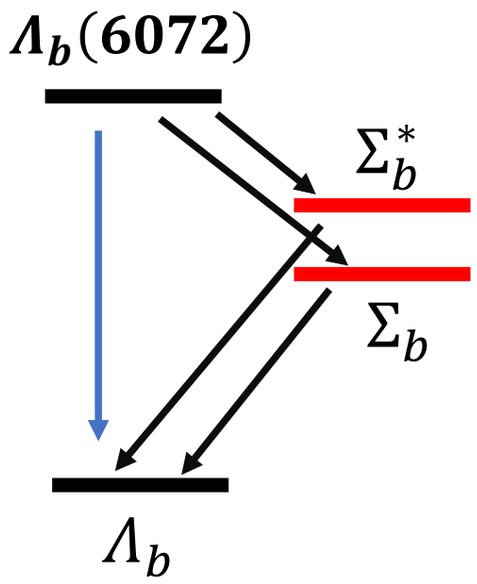


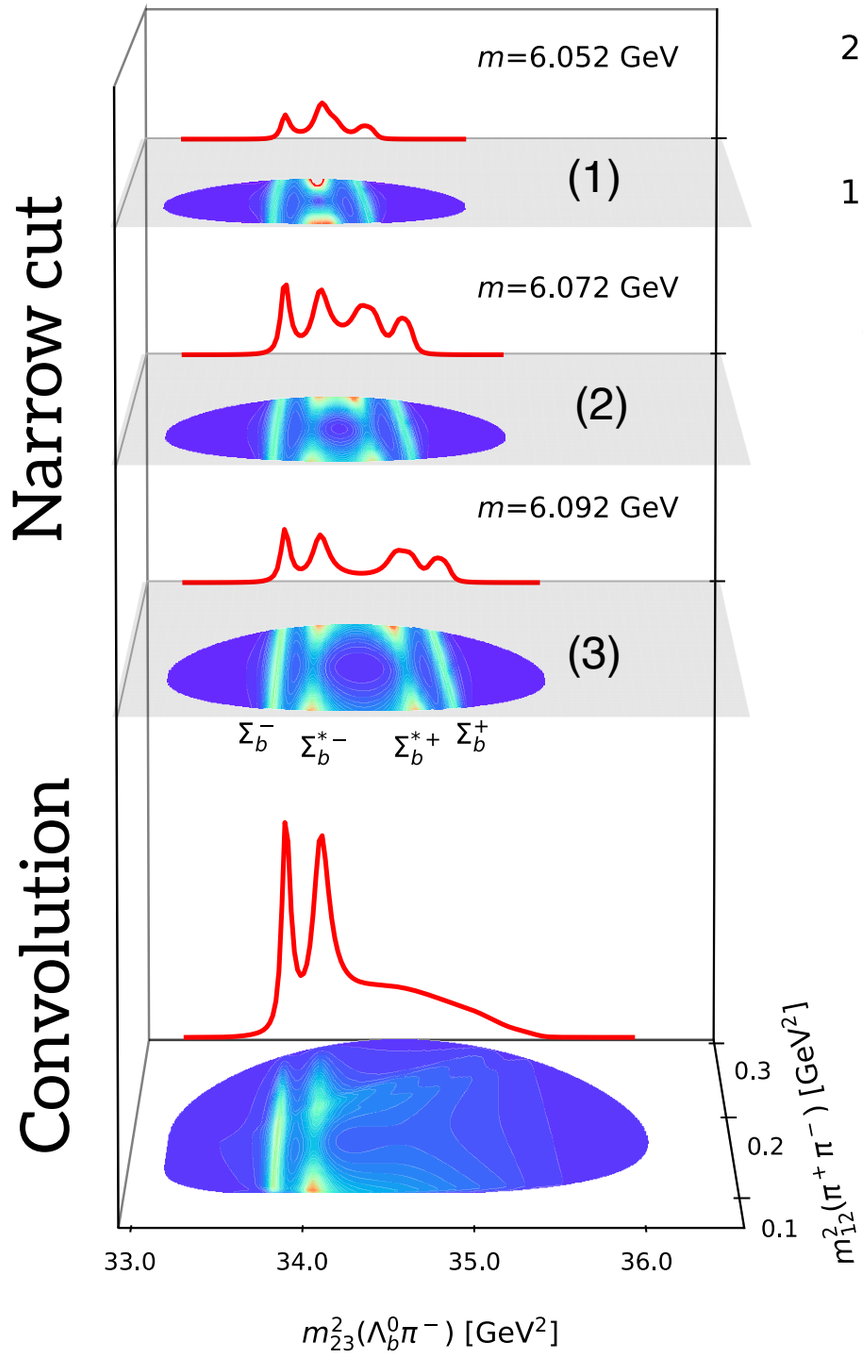
Square plot

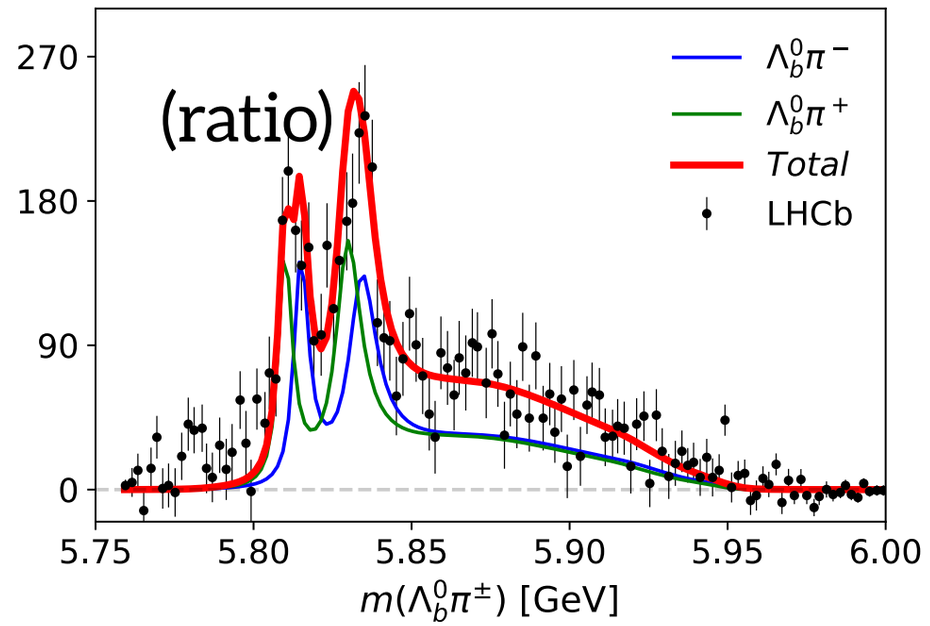
Belle Exp?

Decay of $\Lambda_b^*(6072)$

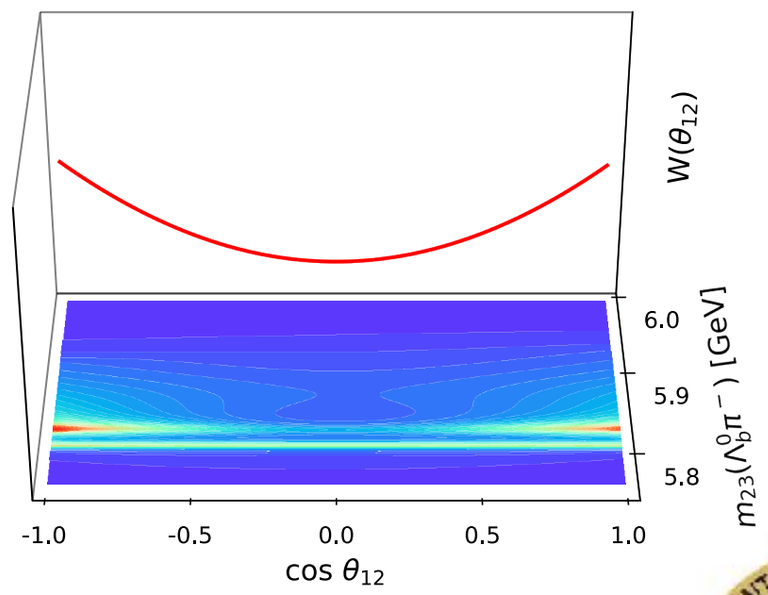








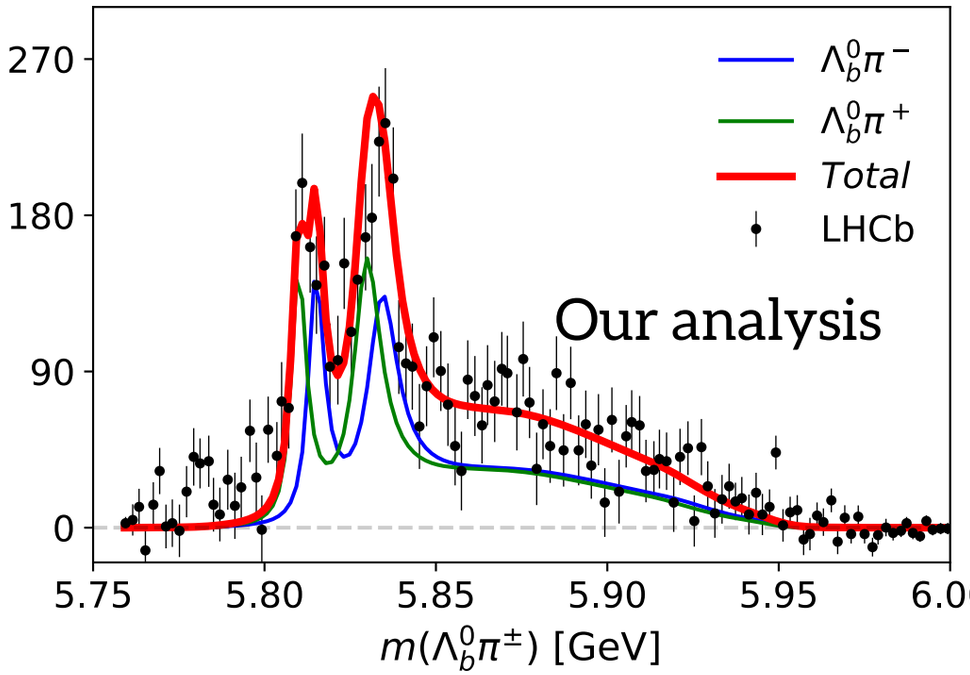
Invariant mass plot



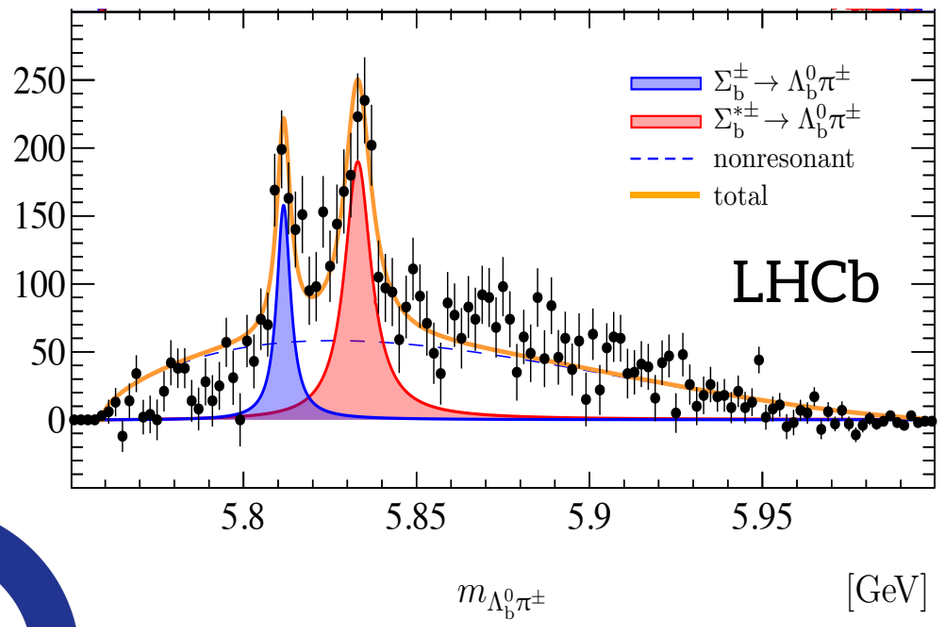
Angular correlation

Arifi, *et. al.* PRD101 111502 (R) (2020)

LHCb analysis on $\Lambda_b^*(6072)$

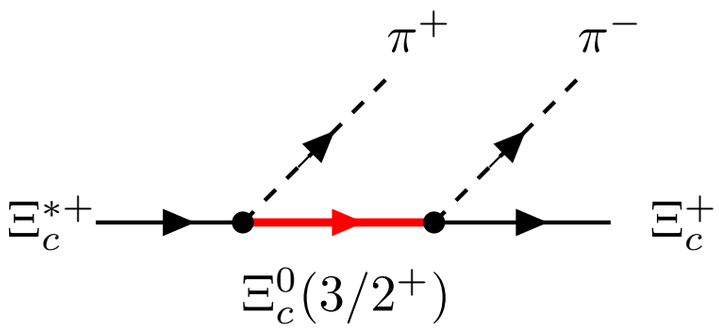


- Background shape is different with the LHCb one.
- It is from the kinematical reflection.
- Sequential decay is sufficient to describe the invariant mass distribution.

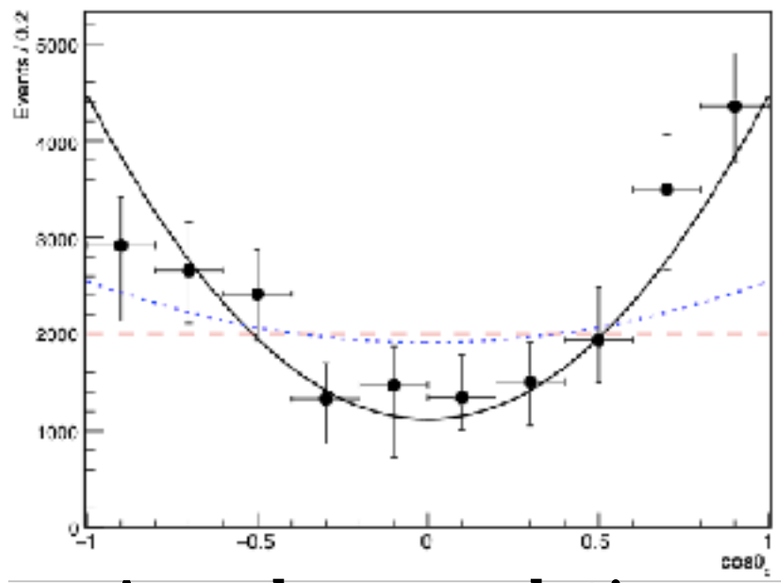


- non-resonant contribution is relatively large.

Decay of $\Xi_c^*(2970)$

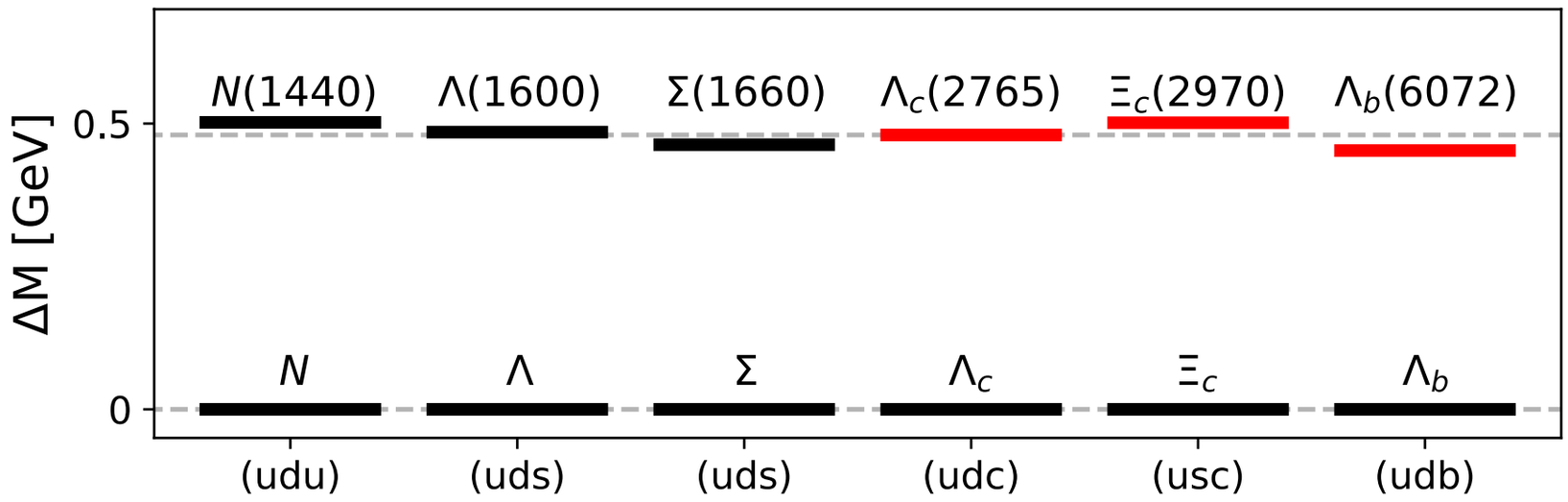


- No kinematical reflection,
- No strong interference
- Clear signal from resonance



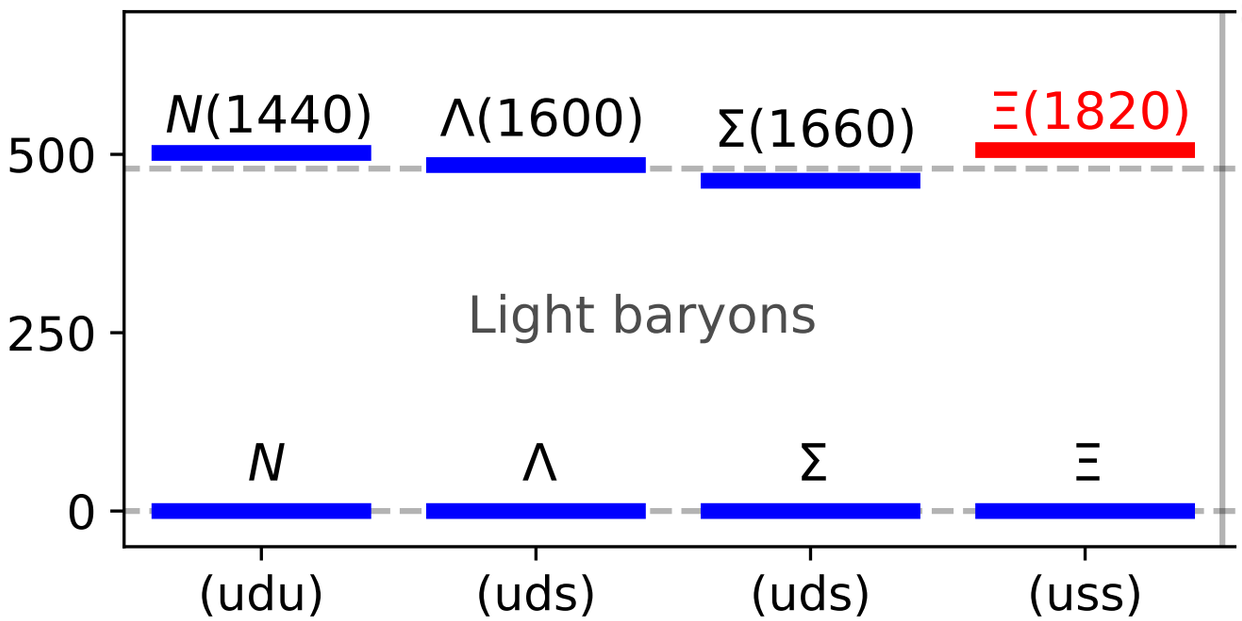
Angular correlation

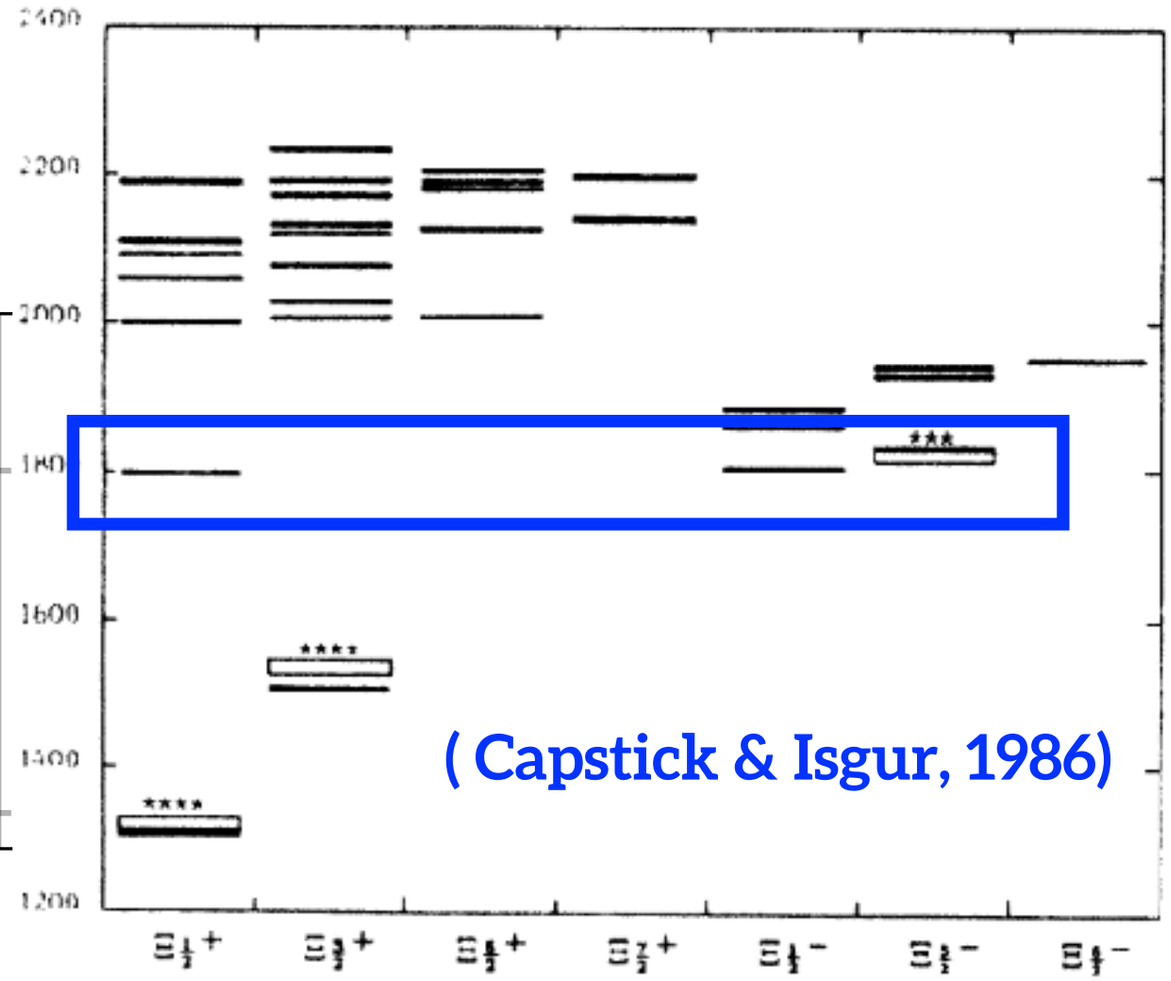
Belle, arXiv: 2007.14700



Search for missing Roper family members

Missing Ξ(1820)





- $\Xi(1820)$ –> $J^P = 3/2^-$ (PDG) (3 star rating)
- ΛK invariant mass
  Γ = 30 MeV. –> $J^P = 3/2^-$
- $\Xi\pi\pi$ invariant mass
  Γ = 50-70 MeV. –> $J^P = 1/2^+$?

- Quark model predicts several states around 1800 MeV, including $3/2^-$ and $1/2^+$.

J-PARC Exp?

Summary

1. Observation of Roper-like heavy baryons

- Spin-parity: Ratio & Angular correlation
- Search for missing resonances

2. Similar behaviors

- New hint to Roper puzzle
- Flavor universality or accidental?

3. Further studies

- Application to higher-excited states of heavy baryons

Thank you for your attention