A new possible resonance at Belle

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What is it? Lambda or Sigma?

- If ?(1663) is the same particle observed by Crystal Ball experiment.
  ?(1663)$\rightarrow\eta\Lambda$

  Assuming it is strong decay, (I, I_z) of ?(1663) is (0,0) thus ? = Λ
  (I, I_z) of η and Λ = (0,0)

- So the key to identify ?(1663) will be observing it from the $\eta\Lambda$ channel.

- Any other possibility? Yes, Pentaquark.
  This state wasn't predicted by the quark model (excited states of three quark interaction)

TABLE I. Energy eigenvalues (in MeV) of the ground and resonance states with total angular momentum and parity J^P from the GBE and OGE RCQMs in comparison to the experimental masses according to the PDG [15]. In each case the number in the parentheses denotes the kth excitation in the respective J^P column starting with $k = 0$. The resonances denoted by mass values in square brackets represent states not definitely classified by the PDG.

Baryon	J^P	Theory GBE	Theory OGE	Experiment
$N(939)$	$\frac{1}{2}^+$	939 (0)	939 (0)	938–940
$N(1440)$	$\frac{1}{2}^+$	1459 (1)	1577 (1)	1420–1470
$N(1520)$	$\frac{3}{2}^-$	1519 (0)	1521 (0)	1515–1525
$N(1535)$	$\frac{1}{2}^-$	1519 (0)	1521 (0)	1525–1545
$N(1650)$	$\frac{1}{2}^-$	1647 (1)	1690 (1)	1645–1670
$N(1675)$	$\frac{5}{2}^-$	1647 (0)	1690 (0)	1670–1680
$N(1700)$	$\frac{3}{2}^-$	1647 (1)	1690 (1)	1650–1750
$N(1710)$	$\frac{1}{2}^+$	1776 (2)	1859 (2)	1680–1740
$\Delta(1232)$	$\frac{3}{2}^+$	1240 (0)	1231 (0)	1231–1233
$\Delta(1600)$	$\frac{3}{2}^+$	1718 (1)	1854 (1)	1550–1700
$\Delta(1620)$	$\frac{1}{2}^-$	1642 (0)	1621 (0)	1600–1660
$\Delta(1700)$	$\frac{3}{2}^-$	1642 (0)	1621 (0)	1670–1750
$\Lambda(1116)$	$\frac{1}{2}^+$	1136 (0)	1113 (0)	1116
$\Lambda(1405)$	$\frac{1}{2}^-$	1556 (0)	1628 (0)	1402–1410
$\Lambda(1520)$	$\frac{3}{2}^-$	1556 (0)	1628 (0)	1519–1521
$\Lambda(1600)$	$\frac{1}{2}^+$	1625 (1)	1747 (1)	1560–1700
$\Lambda(1670)$	$\frac{1}{2}^-$	1682 (1)	1734 (1)	1660–1680
$\Lambda(1690)$	$\frac{3}{2}^-$	1682 (1)	1734 (1)	1685–1695
$\Lambda(1800)$	$\frac{1}{2}^-$	1778 (2)	1844 (2)	1720–1850
$\Lambda(1810)$	$\frac{1}{2}^+$	1799 (2)	1957 (2)	1750–1850
$\Lambda(1830)$	$\frac{5}{2}^-$	1778 (0)	1844 (0)	1810–1830
$\Sigma(1193)$	$\frac{1}{2}^+$	1180 (0)	1213 (0)	1189–1197
$\Sigma(1385)$	$\frac{3}{2}^+$	1389 (0)	1373 (0)	1383–1387
$\Sigma[1560]$	$\frac{1}{2}^-$	1677 (0)	1732 (0)	1546–1576
$\Sigma[1620]$	$\frac{1}{2}^-$	1736 (1)	1829 (2)	1594–1643
$\Sigma(1660)$	$\frac{1}{2}^+$	1616 (1)	1845 (1)	1630–1690
$\Sigma(1670)$	$\frac{3}{2}^-$	1677 (0)	1732 (0)	1665–1685
$\Sigma[1690]$	$\frac{3}{2}^+$	1865 (1)	1991 (1)	1670–1727
$\Sigma(1750)$	$\frac{1}{2}^-$	1759 (2)	1784 (1)	1730–1800
$\Sigma(1775)$	$\frac{5}{2}^-$	1736 (0)	1829 (0)	1770–1780
$\Sigma(1880)$	$\frac{1}{2}^+$	1911 (2)	2049 (2)	1806–2025
$\Sigma[1940]$	$\frac{3}{2}^-$	1736 (1)	1829 (2)	1900–1950
Σ	$\frac{3}{2}^-$	1759 (2)	1784 (1)	

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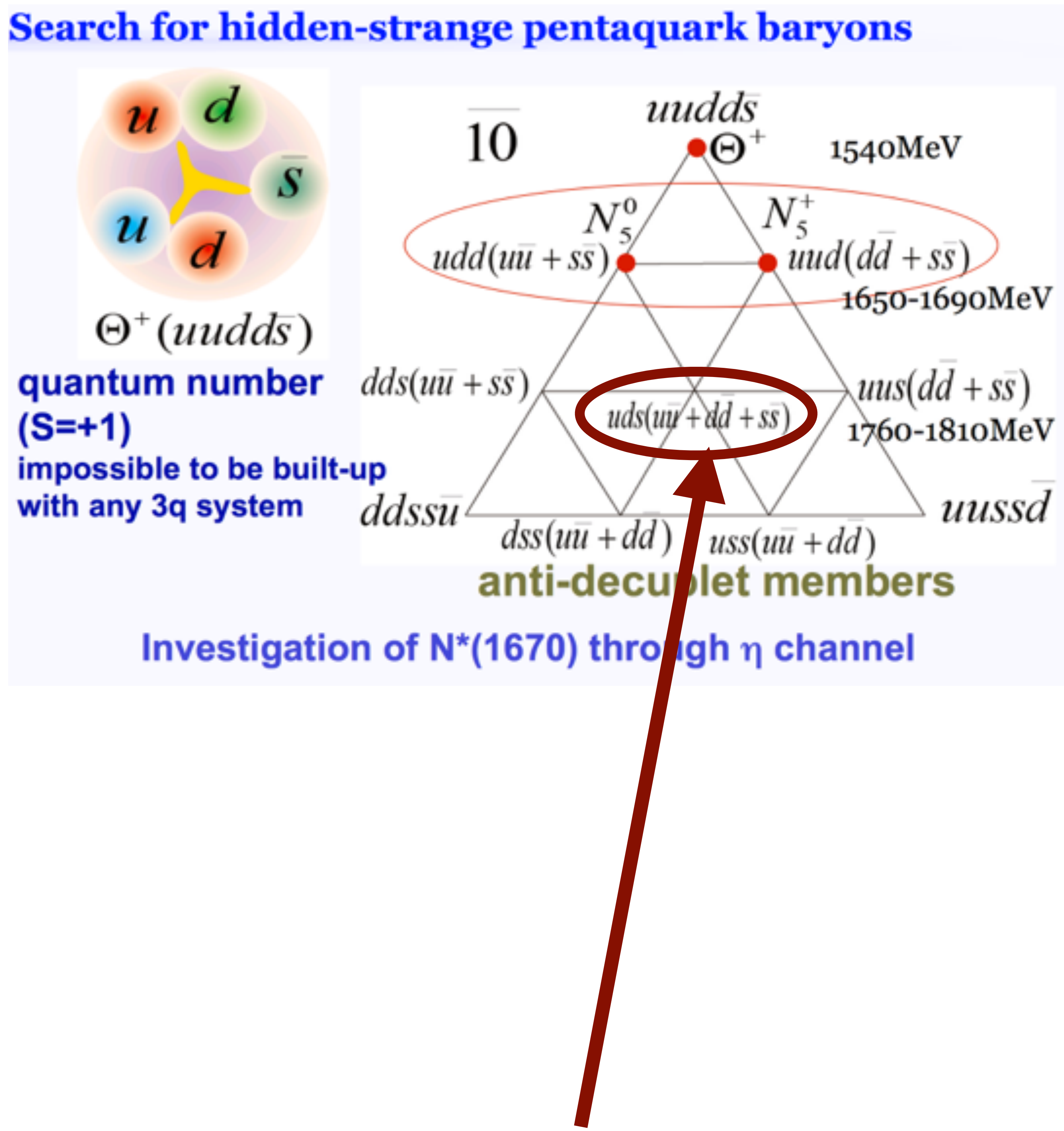


Decaying into ηΛ or Kp

Recent Theories

- 2001: Publication (Kp→ηΛ channel) from Crystal Ball Experiment.
  In conclusion, they did not exclude the possibility of a new state other than $\Lambda(1670)1/2^-$.

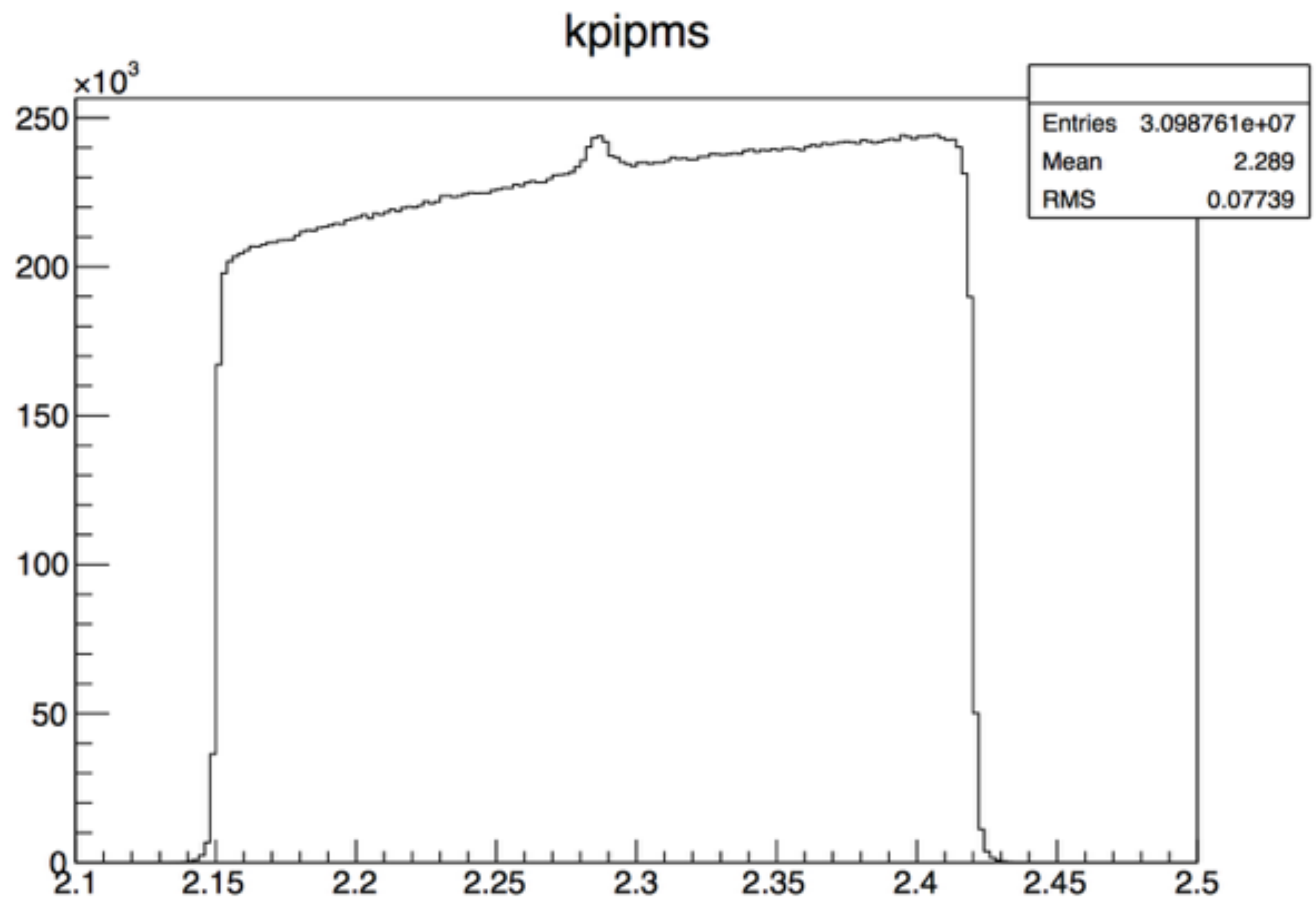
- Liu & Xie: Interpreted Crystal Ball data with current available Λ resonances (effective Lagrangian model).
  Their results show existence of a new narrow resonance.

- Kamano et al: (Dynamical coupled-channels model) Analyzed all K^-p reactions and determined partial-wave amplitudes
  They could reproduce all four-star resonances in PDG and found several new resonances. And in particular proposed a new narrow $J^p=2/3^+$ Λ resonance that strongly couples to ηΛ channel.

- Publications from Theory Groups between 2011 - 2015

Analysis Progress

Still very beginning - Successfully ran Seongbae's codes



Lambda C from kpip invariant mass from exp 73.
Need to optimize cuts

Analysis Steps

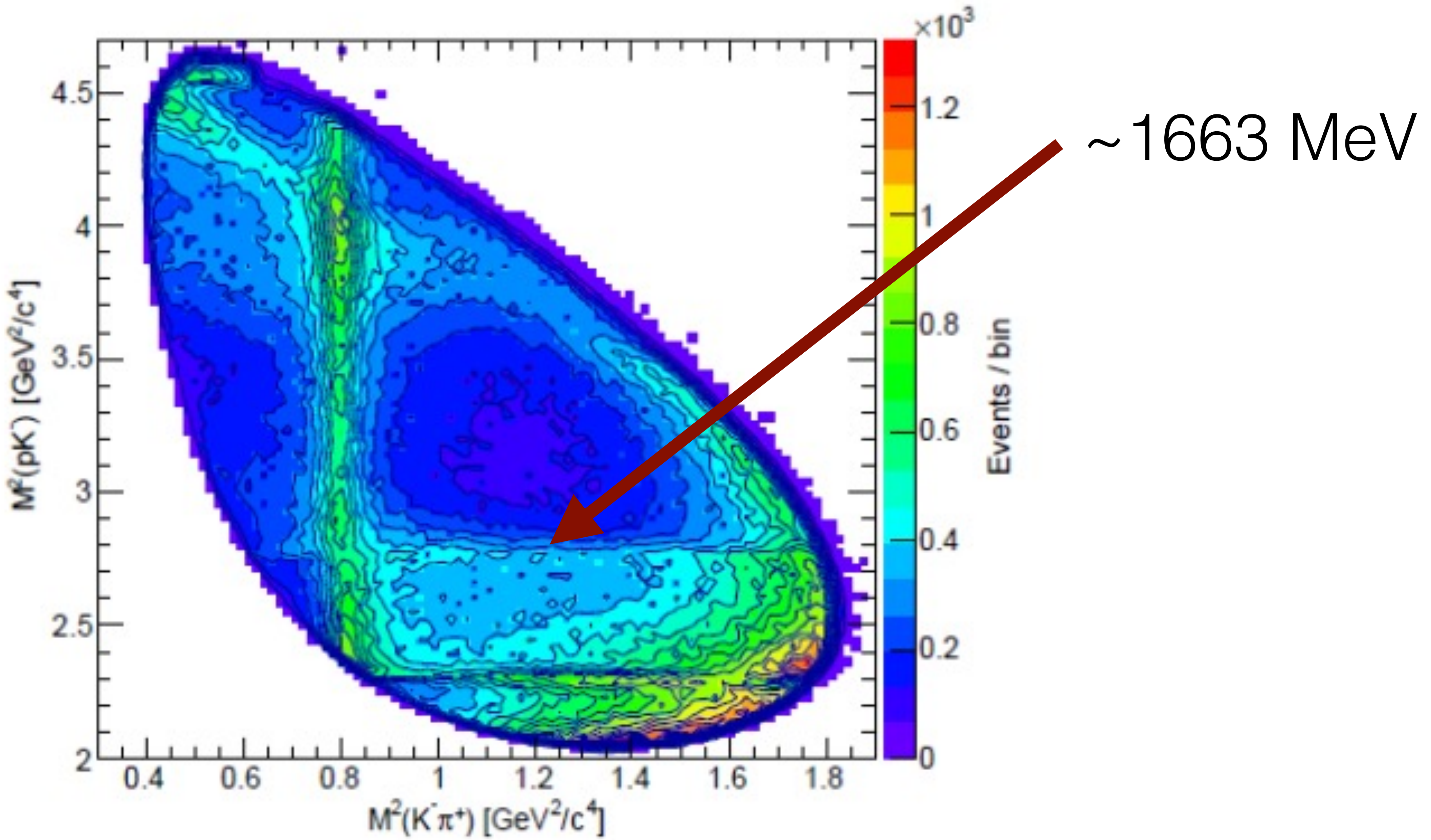
1. Reproduce Seonbae's Result (Lambdac, Kp channel)
   - Dalitz Plot, Kp invariant mass

2. ηΛ invariant mass analysis from Lambdac decays

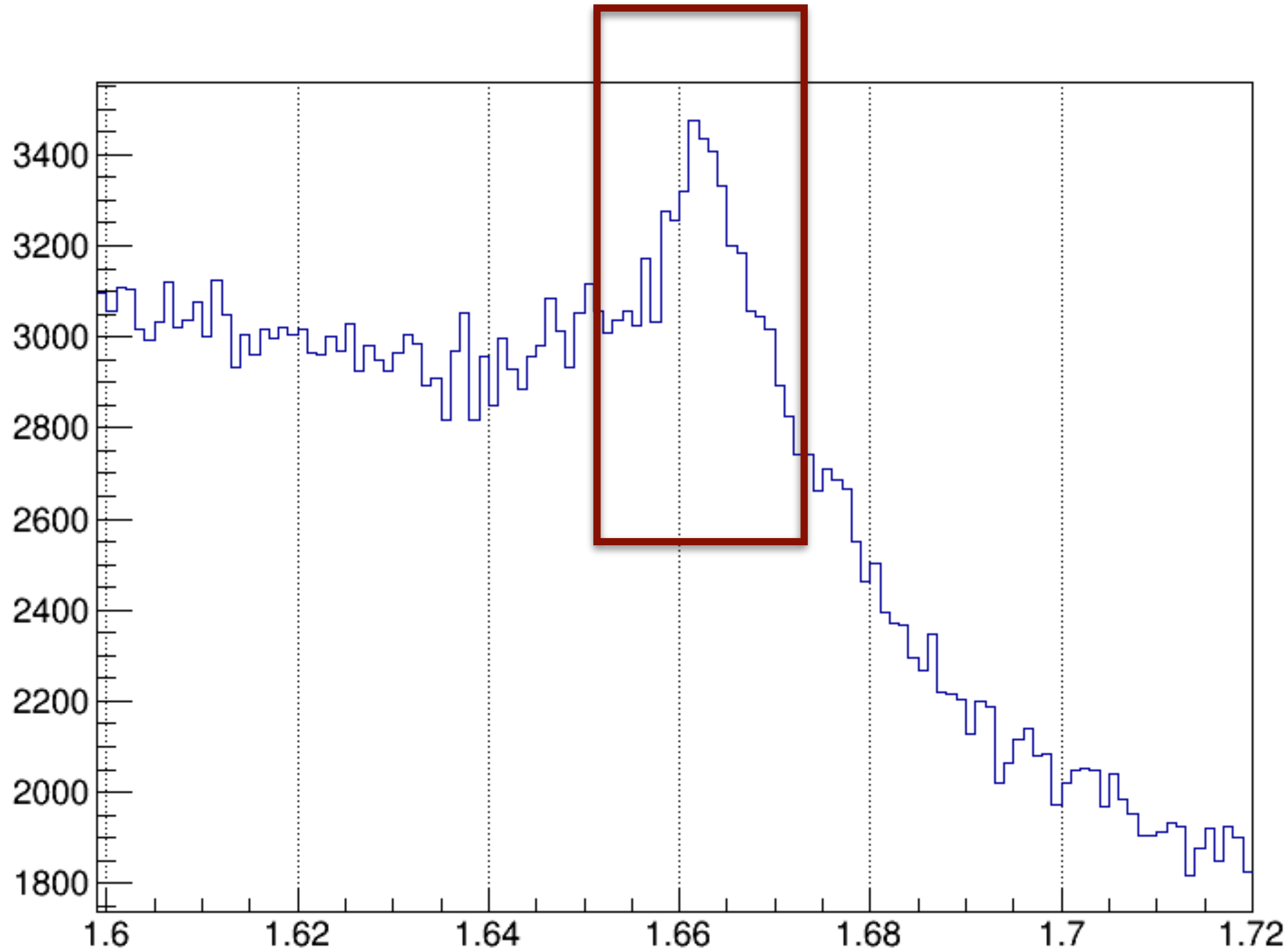
3. Angular correlation analysis

Backups

Decay Mode A new resonance?



A new resonance from Seongbae's analysis



Peak Position is at around 1663 with width ~ 10 MeV (narrower)

Λ(1670): 25-50 MeV

Σ(1660): 40-200 MeV

Σ(1670): 40-80 MeV

M(η)+M(Λ) ≈ 1663.545

Very close to 1663

Not in PDG!

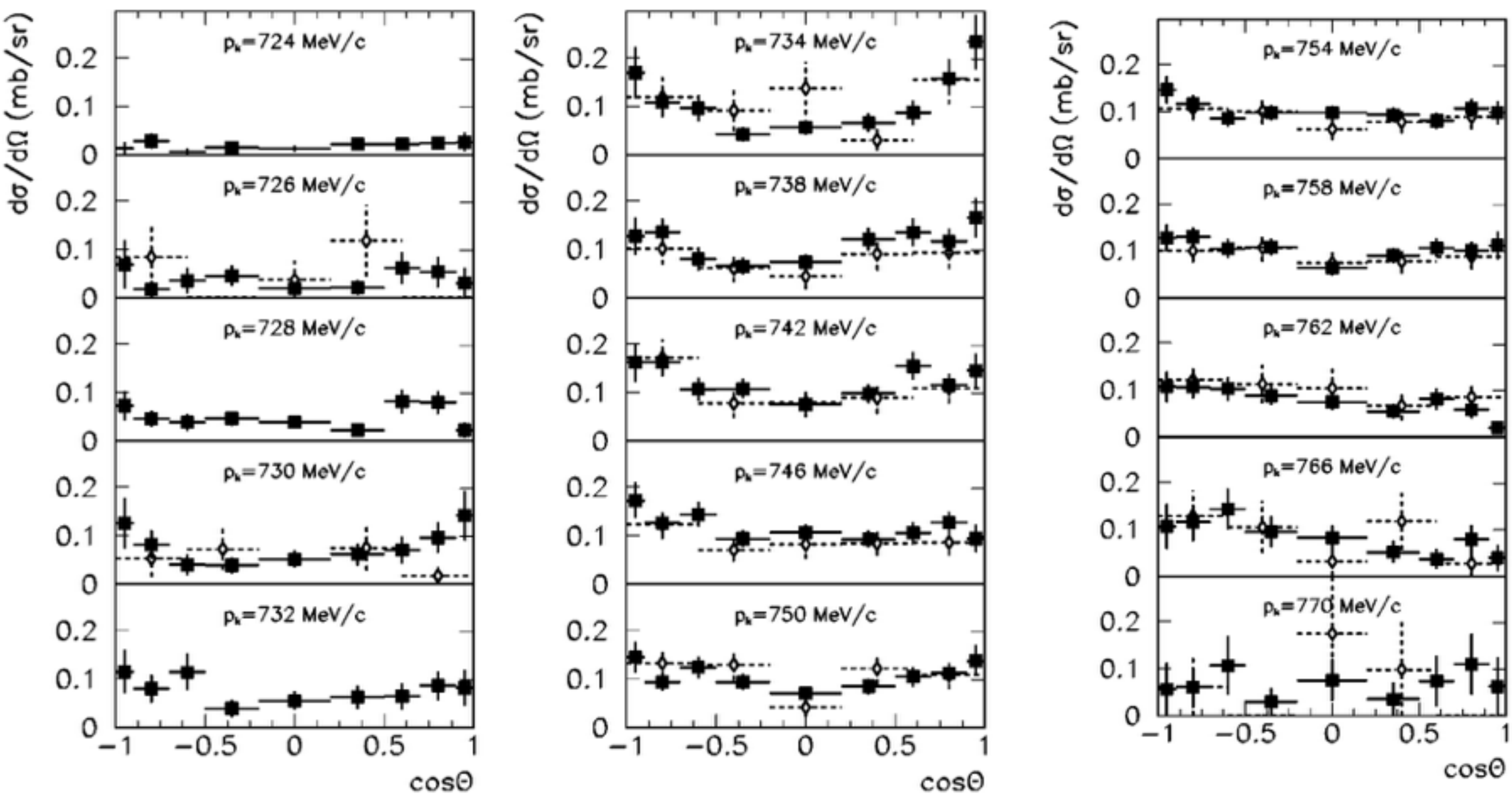
Related Papers

One experiment: Crystal ball experiment ($K^- p \to \eta\Lambda$) (PRC64.055205)
→ evidence for a narrow resonance around p_k = 734 MeV/c ($\sqrt{s} = 1669$MeV)

Two independent Theory group:
Kamano et al. [PRC90.065204, PRC92.025205]
→$J^p = 3/2^+$(P03), M=1671+2-8 MeV, Γ=10+22-4 MeV

Liu & Xie [PRC85.038201, Eur.Phys.J. A51 (2015) 10, 130]
→$J^p = 3/2^-$(D03), M=1668.5±0.5 MeV, Γ=1.5±0.5 MeV

Differential cross section (Crystal ball)



Total cross section (Crystal ball)

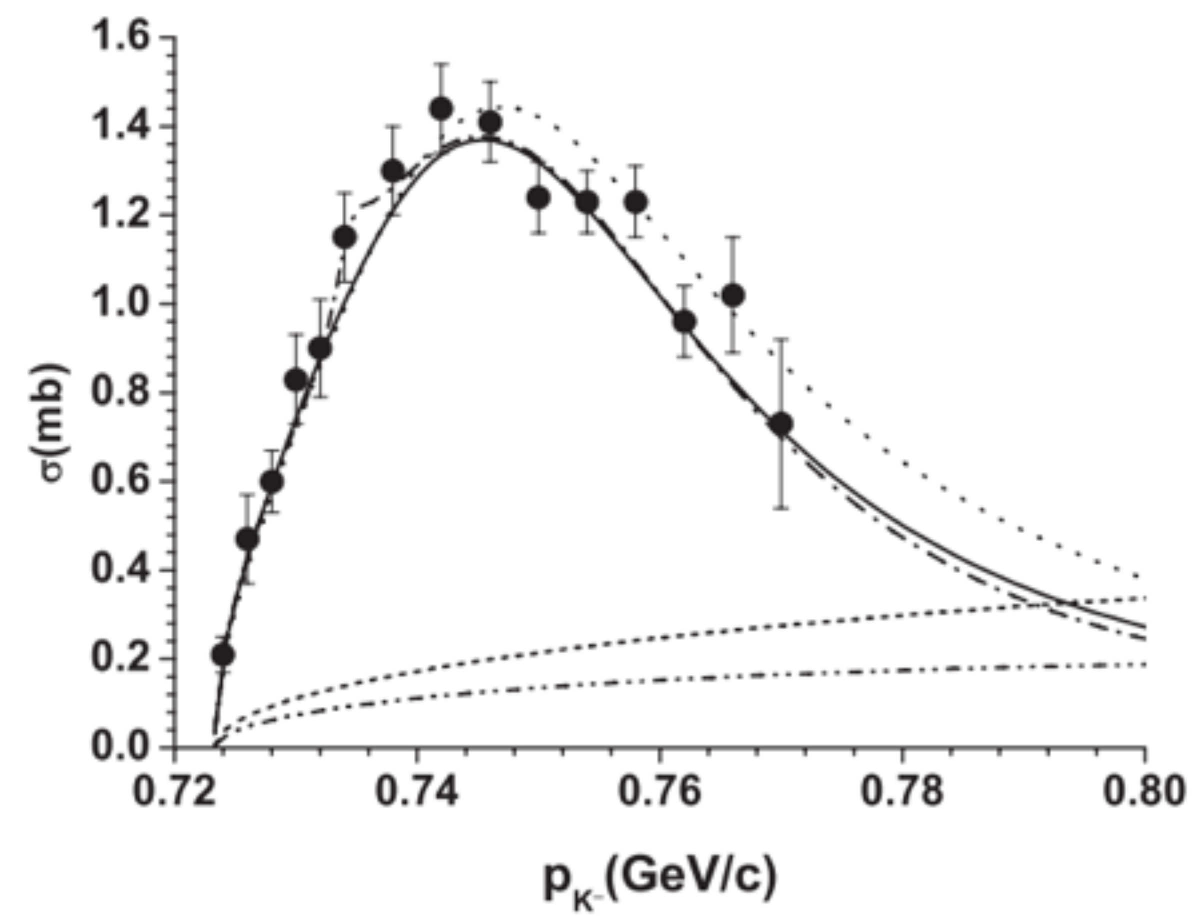


FIG. 2. $K^- p \to \eta\Lambda$ total cross sections compared with the data [1]. Results have been obtained from the best χ^2 fit. The solid line represents the full results, while the contribution from $\Lambda(1670)$, t-channel, and u-channel diagrams are shown by the dotted, dashed, and dot-dot-dashed lines, respectively. The dot-dashed line represents the best results for the total cross sections after including the D_{03} state.

Key measurements

- Peak이 새로운 것을 확인하기 위하여 J=3/2를 확인 (Angular Distribution 분석을 통해)

- K-p→ηΛ 실험에서 J=3/2 컴포넌트가 Differential cross section에서 narrow하게 보였으므로 Resonance(1663)→ηΛ로 가는 채널도 확인해 보고 이 채널의 Angular Distribution도 확인

Spin Measurements

- $\Lambda_c^+ \rightarrow J=1/2$, $\pi \rightarrow J=0$, $\Lambda(1663) \rightarrow J=(?)$
- $\Lambda_c^+ \rightarrow \Lambda(1663) + \pi^+$ Decay Mode 에서 Λ_c^+의 C.M. frame 에서 Λ(1663)의 모멘텀 방향을 z 축으로 잡으면, $L_z = 0$ 이 되고 따라서 Λ(1663)의 $|J_z|=1/2$ 로 Polarized.
- Λ(1663)의 Polarization을 알면, decay particle의 angular distribution으로 부터 Λ(1663)의 스핀을 결정
- $\Lambda(1663) \rightarrow (\eta\Lambda, Kp)$
  ηΛ, Kp 채널 모두 $J=(?) \rightarrow J=0+J=1/2$ 채널

Spin Measurements

1. Λ(1663) J=1/2, |J_z|=1/2 일 때, J=1/2→J=0+J=1/2
   L=0 (S-wave) 밖에 안되고 Angular Distribution→Flat

2. Λ(1663) J=3/2, |J_z|=1/2 일 때, J=1/3→J=0+J=1/2
   L=1 (P-wave)

   J_z=1/2 → J_z'=1/2, -1/2: m=ΔJ_z=0,1 (weight by C-G coefficient)

   $$W(\theta,\varphi) \propto \frac{2}{3}|Y_{10}|^2 + \frac{1}{3}|Y_{11}|^2 \propto 3\cos^2\theta + 1$$

   L=2 (D-wave)

   J_z=1/2 → J_z'=±1/2: m=ΔJ_z=0,1

   $$W(\theta,\varphi) \propto \frac{2}{5}|Y_{20}|^2 + \frac{3}{5}|Y_{21}|^2 \propto 3\cos^2\theta + 1$$

   Angular Ditsribution → U shape distribution (though P and D waves can not be distinguished