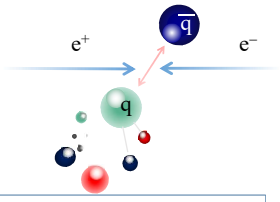
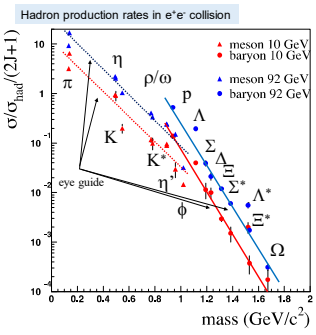
Production rates of hyperons and charmed baryons from e^+e^- annihilation near $\sqrt{s} = 10.52$ GeV

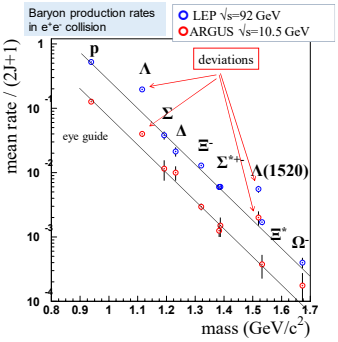
M. Niiyama[1], T. Nakano[2], M. Sumihama[3], T. Matsuda[4] (presenter), Belle Collaboration
[1]Kyoto University, [2]Research Center for Nuclear Physics(RCNP), Osaka University, [3]Gifu University, [4]University of Miyazaki

Abstract
We have measured the inclusive production cross sections of hyperons and charmed baryons from e^+e^- annihilation using a 800 fb^{-1}data sample taken near the $\Upsilon(4S)$resonance with the Belle detector at the KEKB asymmetric-energy e^+e^- collider.
The feed-down contributions from heavy particles are subtracted using our data, and the direct production cross sections are compared for the first time. The results are discussed from the viewpoint of the diquark structure in baryons.



1. Introduction
In e^+e^- annihilation, hadrons are produced after the $e^+e^- \to \gamma^* \to q\bar{q}$ creation and in the fragmentation process.
The observed production cross sections (σ) show an interesting dependence on their masses: $\frac{\sigma}{\sigma_{had}(2J+1)} \propto e^{-\alpha m_{had}}$,
where J, m_{had} and α are the total spin and the mass of a hadron and a slope parameter, respectively.





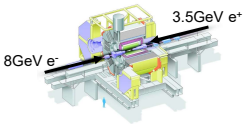
- Different slope for mesons and baryons.
- quark counting?
- What about "exotic" hadrons like Ξ(1530) ?

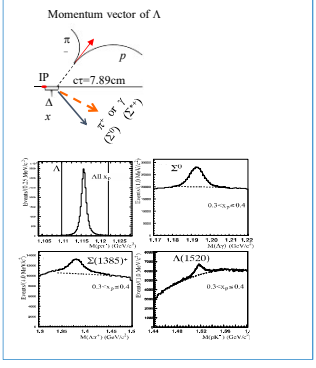
Issues (Motivation)
- Feed down contributions from heavy particles is subtracted ?
- Large errors in ARGUS results
- How about charmed baryons?

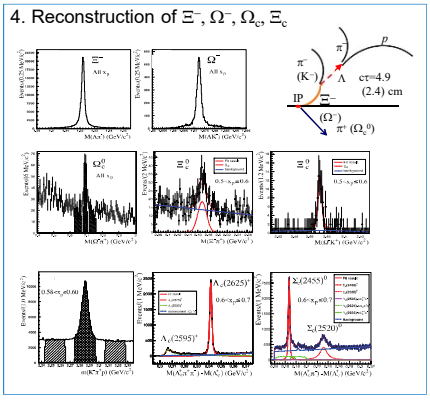
⇒Study at Belle !

- Baryon production: color suppression to form color-singlet. combination among random quark colors.
- Diquark-antidiquark production model can explain relatively high production rate.
  Relativistic-string model.
  B. Andersson, G. Gustafson, T. Sjostrand, Physica Scripta 32, 574, 1985.
- Higher rates for Λ and Λ(1520) in ARGUS and LEP.
- J=0, light (ud) diquark in Λ?
  R.L. Jaffe, Phys.Rept.409,1 (2005)
  A. Selem, F. Wilczek, hep-ph/0602128

2. Belle data of KEK, Japan
Integrated luminosity
: 562. fb^{-1}@ "on Υ(4S) resonance" data for charmed baryons (√s =10.58 GeV)
: 79.3 fb^{-1}@ continuum data for hyperons, charmed baryons (√s =10.52 GeV)

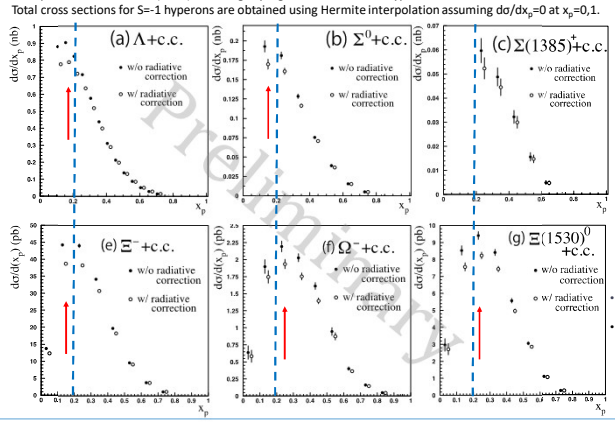


3. Reconstruction of S=-1 hyperons


4. Reconstruction of Ξ⁻, Ω⁻, Ωc, Ξc


5. Inclusive differential cross sections, hyperons
"Inclusive" cross sections (including feed-down contributions from heavy particles) are obtained as a function of hadron scaled momentum (x_p):
$x_p = \frac{p}{\sqrt{\frac{s}{4}-M^2}}$, where M, p are mass and CM momentum respectively.

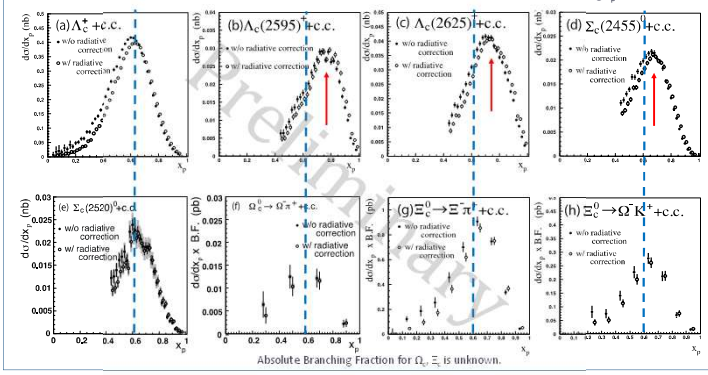
- Peaks around x_p=~0.2-0.3 ⇒ hyperons are produced in soft processes.
- Peak positions for Ω⁻ and Ξ(1530) seem slightly higher than the other hyperons.
- Total cross sections for S=-1 hyperons are obtained using Hermite interpolation assuming $d\sigma/dx_p$=0 at x_p=0,1.



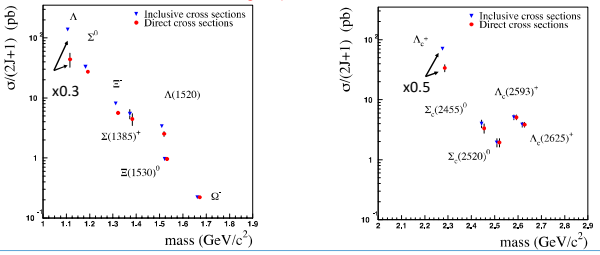
- Used only continuum data.
- Error bar represent statistical fluctuation.

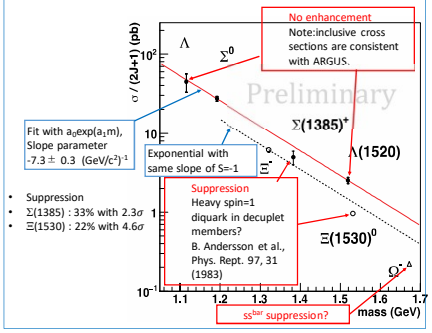
6. Inclusive differential cross sections, charmed baryons
- Peaks around x_p=~0.6-0.7 ⇒ charm quarks are produced in $e^+e^- \to \gamma^* \to c\bar{c}$.
- Peak positions for heavier particles seem higher.
- More energetic fragmentation process is necessary to produce heavy particle?
- Total cross sections of excited states are obtained by fitting Lund fragmentation model.

- Used "on Υ(4S)" and continuum data.
- B-meson decay from Υ(4S) contribution concentrates in low x_p and is eliminated by selecting x_p>0.44.

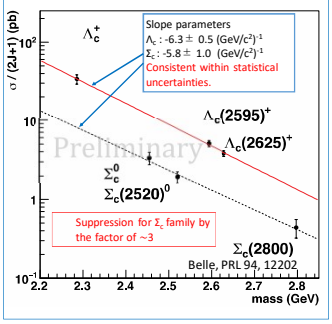


7. Feed-down subtracted (direct) cross section
- The feed-down contributions from heavy particles are subtracted using our data, and the direct production cross sections are compared for the first time.
- Cross sections before feed-down subtraction are consistent with previous measurements but much higher precision (previous measurements are not shown in the figures.).

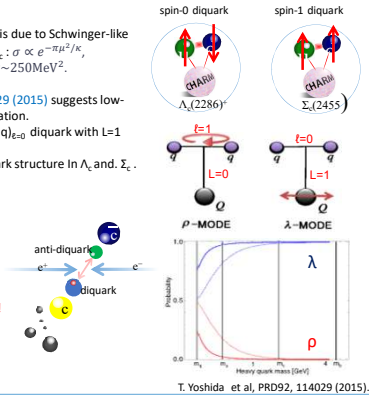


8. Results for hyperons


- Suppression
- Σ(1385) : 33% with 2.3σ
- Ξ(1530) : 22% with 4.6σ

9. Results of charmed baryons


10. Discussion
- Assuming that a c-quark picks up a diquark from vacuum is due to Schwinger-like "tunnel effect", the production cross sections of Λ_c and Σ_c : $\sigma \propto e^{-\pi\mu^2/\kappa}$, where μ: diquark mass, κ: gluonic string tension and κ/π~250MeV^2.
  B. Andersson et al., Phys. Scripta. 32, 574 (1985).
- Quark model prediction by T. Yoshida et al, PRD92, 114029 (2015) suggests low-lying P-wave excitation is dominated by the λ-mode excitation.
- $\Lambda_c(2593)$ (1/2-) and $\Lambda_c(2625)$ (3/2-) are composed of $(qq)_{\ell=0}$ diquark with L=1 excitation relative to charm quark.
- Difference of production rates may be related with diquark structure In Λ_c and. Σ_c .
  Λ_c : spin-0 light diquark ("good" diquark),
  Σ_c : spin-1 heavy diquark ("bad" diquark).
- $\sigma(\Sigma_c)/\sigma(\Lambda_c) = 0.27 \pm 0.07$.
- Mass difference of spin-1 and spin-0 diquarks
  $m(ud_1)^2 - m(ud_0)^2 = (8.2 \pm 0.8) \times 10^4$ (MeV/c^2)^2.
  ref. $490^2 - 420^2 = 6.4 \times 10^4$ (MeV/c^2)^2
  B. Andersson et al., Phys. Rept. 97, 31 (1983).
- The obtained difference is slightly higher than reference, but consistent with the spin-1/0 diquark mass difference!



11. Summary
- Production cross sections of hyperons and charmed baryons are measured near the Υ(4S) energy using Belle data.
- $d\sigma/dx_p$ distributions for hyperons are measured.
  - Slightly higher Peak positions for Ω- and Ξ(1530).
- $d\sigma/dx_p$ distributions for charmed baryons are measured.
  - Peak positions for heavier particles seem higher.
- "Inclusive" total cross sections for hyperons are mesured.
  - Consistent with previous measurements with much higher precision.
- Direct total cross sections are obtained.
  - Clear exponential dependence on baryon masses.
  - No enhancements for Λ, Λ(1520).
  - Suppression of decuplet hyperons and Σ_c family.
  - Suggesting diquark structure in ground and low-lying Λ_c, Σ_c.
- Next, exotic candidates, heavier Λ_c resonances …
  - Input of absolute Branching Fraction for Ξ_c is helpful.

Please see arXiv:1706.06791 [hep-ex] for more information.
An updated vesion of this study will be submitted to Phys. Rev. D.