Hadron physics at LEPS/ LEPS II and Belle

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Contents

• LEPS

- coherent φ-meson photoproduction from ⁴He.
- LEPS2
	- beam asymmetry (Σ) for η -meson photoproduction.
- Belle
	- production rates of hyperons and charmed baryons from e⁺e⁻ annihilation near $\Upsilon(4S)$.

Coherent φ-meson photoproduction from 4He

LEPS facility

- Backward Compton scattering of laser photons with 8 GeV electrons in SPring-8
	- 351 nm Ar laser (3.5eV) $8W \sim 2.4$ GeV photon
	- 266nm Solid+BBO (4.6eV) 1W ~3.0 GeV photon
- Laser Power ~6 W (351nm) Photon Flux ~1 Mcps (2.4 GeV)
- E_{γ} measured by tagging a recoil electron E_{γ} >1.5 GeV, ΔE_{γ} ~10 MeV
- Laser linear polarization 95-100% \Rightarrow Highly polarized beam

Experimental setup

Motivation (I): why φ?

Pomeron exchange:

- Dominant process at high energies
- Not well understood at low energies
- Natural-parity
- Multi-gluon dynamics

Pseudo-scaler meson exchange:

- Dominant process at low energies
- Well established process
- Unnatural-parity
- \cdot π , η meson exchange

Motivation (I): why φ?

N' N

 π, η Ω
due to C-parity

Pomeron exchange:

- Dominant process at high energies
- Not well understood at low energies
- Natural-parity
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Pseudo-scaler meson exchange:

- Dominant process at low energies
- Well established process
- Unnatural-parity
- \cdot π , η meson exchange

Motivation (II): why ⁴He?

- Pseudo scalar meson exchange is forbidden.
- Pomeron (or gluonic) dynamics appears directly.

Motivation (III): why photon beam? $\mathcal{A} = \mathcal{A} \cup \mathcal{A}$ target particle is a helium-4 nucleus at rest. The three-st. The three- \blacksquare Motivation (III); why p \mathbf{S} with linearly polarized photons, as a function of the function of th **0 0.2 First, We present the External External Structure in Terms** 3 tributions for the coherent $\mathbf{X} = \mathbf{X} + \mathbf{A} + \math$ **0.6 0** ⁷ dimensional decay angular distribution *W*(cos ⇥*, ,*) **EXECUTE: WE WATER WINCONS, and the UNIVERSITY POINT CONSUMER** polar (⇥) and azimuthal () angles of the *K*⁺ ⁹ in the \blacksquare where \blacksquare and lower signs in \blacksquare amplitudes with natural (*I*N) and unnatural (*I*U) parity exchange, respectively. The typical example of the natural and where the upper and lower signs in \sim 1–3 correspond to the upper and lower signs in \sim 1–3 correspond to the upper signs in \sim 1–3 correspond to the upper signs in \sim 1–3 correspond to the upper signs in \sim 1–3 amplitudes with natural (*I*N) and unnatural (*I*U) parity exchange, respectively. The typical example of the natural example of the natural and \mathbf{p} **PII** JLab \sim \sim The double polarization observables related to the beam polarization and polarization of the outgoing vector mesons are described in terms of spin-density matrices ¹*i j* , which are described in terms of spin-density matrices ¹*i j* , which determine the vector-meson determine the vector-meson determined vertices

• Spin density matrix elements (SDME) α $\frac{1}{2}$ seudoscalar-meson exchange amplitudes, re-· Spin dens determine the vector-meson decay distributions in its rest $\overline{}$

$$
\rho_{\lambda\lambda'}^0 = \frac{1}{N} \sum_{\alpha,\lambda_{\gamma}} I_{\alpha;\lambda,\lambda_{\gamma}} I_{\alpha;\lambda',\lambda_{\gamma}}^{\dagger},
$$
\n
$$
\alpha,\lambda,\lambda_{\gamma} \text{ : helicities of nucleon, } \beta_{\lambda\lambda'}^1 = \frac{1}{N} \sum_{\alpha,\lambda_{\gamma}} I_{\alpha;\lambda,-\lambda_{\gamma}} I_{\alpha;\lambda',\lambda_{\gamma}}^{\dagger}
$$
\nmeson, photon

where *k*\$ and *px* are the photon momentum and the *x* com-

larity of exertation. Partiers in

larization. The polarization vectors of the linear ($\frac{1}{2}$

 \mathbb{R}^2

 $\rho_{\lambda\lambda'} = \frac{1}{N} \sum_{\alpha,\lambda_{\gamma}} I_{\alpha;\lambda,\lambda_{\gamma}} I_{\alpha;\lambda',\lambda_{\gamma}},$ $\alpha,\lambda,\lambda_{\gamma}$: helicities of nucleon, $p_{\lambda\lambda}^1 = \frac{1}{N} \sum I_{\alpha:\lambda} = \lambda I_{\alpha:\lambda}^{\dagger}$ *i meson*, photon U *t* $\frac{1}{\sqrt{2}}$

.
"After the second term describes the interaction of the interaction of the photon of the photon of the photon

14 Decay angular distributions in GI frame ¹⁵ dimensional decay angular distributions: Spin single-flip or non-flip $\frac{1}{2}$ *,* $W(\Phi) = N_2(1 - 2\text{Re}\rho_{1-1}^0\cos 2\Phi)$ Interference of helicity double-flip and non-flip **P** = *M*₂ = $I_{fi}^{\prime} \sim -\frac{\partial_{\lambda_{\phi} \lambda_{\gamma}} u_f k u_i + \partial_{\lambda_{\phi} 0} k_{\gamma} u_f \mathbf{\mathscr{E}}_{\lambda_{\gamma}} u_i}{\sin \theta}$ \overline{x} polar () angles of the *K*- 1 in the *R* 9 in the *K* 100 angle and the attention the matter $W(\cos \Theta) = N_1 \{(1 - \rho_{00}^0) \sin^2 \Theta + \rho_{00}^0 \cos^2 \Theta\}$ $W(\Phi) = N_2(1-2{\rm Re}\rho_{1-1}^0\cos2\Phi)$ Interference of helicity double-flip and non-flip Pomeron exchange amplitude Titov and Lee, F \overline{u}_f^P \sim δ_{λ} _φ λ _γ \overline{u}_f $\overline{k}u_i + \delta_{\lambda}$ _φ0 k _γ \overline{u}_f $\overline{\overline{k}}$ _{λγ} u_i ₊ $\sqrt{2}\lambda$ _γ $\overline{\mu}$ $\int_{R} p_{x} \frac{k \cdot q}{\sqrt{1 - \frac{1}{k^{2}}}}$ *,* Decay angular distributions $W(\cos \Theta) = N_1 \left\{ (1 - \rho_{00}^0) \sin^2 \Theta + \rho_{00}^0 \cos^2 \Theta \right\}$ ¹¹ cos 2)*,* $W(Y) = W_2(1 - 2W_1 - 1W_2)$ $-$ 2**R**e ρ_{1-1} or nelicity double-life and no \sim S $\frac{1}{2}$ $\frac{1}{2}$ $u_i + \delta$ ₂ $\overline{u_i}$ $\overline{u_i}$ $\overline{u_i}$ $\overline{u_i}$ $\overline{u_i}$ Interference of helicity double-flip and non-flip • Decay angular distributions in GJ frame Pomeron exchange amplitude Titov and Lee, PRC67,065205 *I* 2*mi*&\$ $distributions$ $iN'(\Phi) = N_2(1-2{\rm Re}\rho_{1-1}^0\cos2\Phi) \ .$ Interference of helicity double-flip and no *Ifficially* abusic inperior inperior I_{fi}^P \sim δ_{λ} $_{\phi^{\lambda}$ $_{\gamma}}$ *¯* \overline{u}_f k u_i + δ_{λ} _φ0 k _γ *¯* I_{fi}^P $\sim -\frac{\delta \lambda_{\phi} \lambda_{\gamma} \bar{u}_f k u_i + \delta \lambda_{\phi} 0 k_{\gamma} \bar{u}_f k_{\lambda_{\gamma}} u_i}{\sqrt{2} \lambda_{\gamma} p_x}$ \mathbf{r} *mfmi* ;&#&\$ 2*mi*&\$ in non-flinear T_{equation} *¯ ¯* Pomeron exchange amplitude Titoy and Lee, PRC67,065205 *¯* • Decay angular $\frac{11}{1000}$ the spin single-tlip c $W(\Phi) = N_2(1 - \Phi)$ $\left(1.7, 2.0, 2.0\right)$ $\mathcal{V}(\cos \Theta)$ = \overline{M} , \overline{M} ,;/!,/! \overline{M} (1 0 $(1, 0)$ \mathbf{D}_{Ω} \overline{M} (1 Ω ₀, 0 Ω _{0, 0} \blacksquare interference of helicity doubleeca *i* **y angular distr** $\frac{1}{2}$ pin \overline{c} *N* . (1, 2D, 0, 0, 1, 25) \bigcap where the symbol of the symbol of the symbol of the symbol $f(x)$ inconduction baryons, and the normalization factor $\frac{1}{2}$

$$
I_{fi} \sim -\frac{\partial_{\lambda_{\phi}\lambda_{\gamma}} u_{f} \kappa u_{i} + \partial_{\lambda_{\phi}0} \kappa_{\gamma} u_{f} \varepsilon_{\lambda_{\gamma}} u_{i}}{\text{non-flip}}
$$
\n
$$
W(\Phi - \Psi) = N_{3} \{ 1 + 2P_{\gamma} \overline{\rho}_{1-1}^{1} \cos 2(\Phi - \Psi) \}
$$
\n
$$
\text{Parity of exchanged particle in t-channel}
$$
\n
$$
I = \begin{cases} \n\frac{1}{2} & \text{if } \lambda_{\phi} u_{i} \text{ is a random with } \Delta u_{i
$$

 μ_i μ_i μ μ μ μ μ μ <u>index</u> u: nucleon w.f.
List in the top my .
2 **nucleon w.f.** with small lines on the small lines on the small lines on the small lines on the small lines o k, p $_x$: photon mom. ucleon momentum in x \boldsymbol{i} $\chi^*_{\lambda} u_i$

– 1

Motivation (III): why photon beam? er en die besteht der die Staat van die Andere von die besteht der Engels andere von d Related to the spin-density-matrix elements tion (III): why photon beam? 10 - meson rest frame and the azimuthal and the azimuthal and the azimuthal and the azimuthal and the azimutha
The azimuthal angle () of a simulate contract of a simulate contract of a simulate contract of a simulate cont

• For helicity-conserving processes, parity asymmetry is erving processes, parity asymmetry is the overall center-of-mass \sim

$$
\rho_{1-1}^1 \ = \ -\mathrm{Im}\rho_{1-1}^2 \qquad \rho_{1-1}^1 = \frac{1}{2} \frac{|I_0^N|^2 - |I_0^U|^2}{|I_0^N|^2 + |I_0^U|^2} \qquad \text{Natural (unnatural)}\namplitudes
$$

Natural (unnatural) parity exchange amplitudes

√ Pure natural-parity exchange: $(\rho_{1-1}^1 - Im\rho_{1-1}^2)/2 = +0.5$ √ Pure unnatural-parity exchange: $(\rho_{1-1}^1 - Im\rho_{1-1}^2)/2 = -0.5$ ¹⁴ tion (*P*) [22]. Following Ref. [23], one obtains five one--parity exchange: $(\rho_{1-1}^+-1m\rho_{1-1}^+)/Z=+0$ $\frac{1}{2}$ when we will work the $\frac{1}{2}$ and $\frac{1}{2}$ $\frac{1$

Parity filter for t-channel reaction

Previous measurements (I) γ p → φ p

- r¹ 11 and 12 Energy dependence). The contract of the second state \mathbb{R}^n • W(cos θ) $\rightarrow \rho^0_{00}$ \rightarrow No helicity single-flip.
- ρ^1_{1-1} ~0.2 \rightarrow N/(N+UN)~0.7 \rightarrow Strong natural parity exchange (no energy dependence).

Previous measurements (II)γ D → φ D to previous mea

in the angular bins and polar angle distribution α is α **Example 23/4***3* Note: pion exchange is forbidden due to isospin conservation.

tions of *d*σ^γ ^d*/dt* at zero degree by a model including pomeron and η-exchange

underestimates the data.

than 1*.*89 GeV*/c*2. Afterwards the average decay asymme-

φ-meson from 4He analysis

Angular distributions Anguilar dictributions ²² density matrix elements were extracted. $\overline{3}$ ³⁹ that for the + *p* ! + *p* and + *D* ! + *D* reac- $E1: 1.985 < E_{\gamma} < 2.185$ GeV, $E2: 2.185 < E_{\gamma} < 2.385$ GeV First, we present the ! *^K*⁺*K* ² decay angular dis-Angular distributions for the contract \bm{s} First, we present the ! *^K*⁺*K* ² decay angular dis-**3 Angular distributions** ⁵ *|t|*min is the minimum *|t|* under the assumption that the First, we present the ! *^K*⁺*K* ² decay angular dis-Angular distributions for the contractions of $\bf 4H$ at for the second and the second of the $\frac{1}{\sqrt{2}}$ $\frac{1}{\sqrt{2}}$

 $W(\Phi) = N_2(1 - 2\text{Re}\rho_1^0$, $\cos 2\Phi$ $W(\vec{A} - \vec{W}) = \vec{M} (1 + \vec{M})$ $W(\Psi - \Psi) = N_3 \{1 + 2P_{\gamma} \rho_{1-1}^{\star} \cos 2(\Psi - \Psi)\}$ $W(\cos \Theta) = N_1$ $W(\cos \Theta) = N_1 \left\{ (1 - \rho_{00}^0) \sin^2 \Theta + \rho_{00}^0 \cos^2 \Theta \right\}$ $\Phi) = N_2(1 - 2\text{Re}\rho_{1-1}^0\cos 2\Phi)$ $\eta_3\{1+2P_\gamma\rho_{1-1}^*\cos2(\Phi-\Phi)\}$ Ψ $W(\Phi - \Psi) = N_3 \{1 + 2P_\gamma \overline{\rho}_{1-1}^1 \cos 2(\Phi - \Psi)$ $N_1\{(1-\rho_{00}^0)\sin^2\Theta + \rho_{00}^0\cos^2\Theta\}$ $V(\cos \Theta) = N_1 \{ (1 - \rho_{\infty}^0) \sin^2 \Theta + \rho_{\infty}^0 \cos^2 \Theta \}$ $W(\Phi) = N_2(1 - 2\text{Re}\rho_{1-1}^0\cos 2\Phi)$ $N_3 \bigl\{ 1+2P_\gamma\overline{\rho}_{1-1}^1\cos 2(\Phi-\right.$ $\overline{}$ $W(\Phi - \Psi) = N_3 \{ 1 + 2P_{\gamma} \overline{\rho}_{1-1}^1 \cos 2(\Phi - \Psi)\}$ $(1 - \rho_{00}^0) \sin^2 \Theta + \rho_{00}^0 \cos^2 \Theta$ $P(Y_2(1 - 2\text{Re}\rho_{1-1}^0\cos 2\Phi))$ $\left\{1+2P_{\gamma}\overline{\rho}^{1}_{1-1}\cos2(\Phi-\Psi)\right\}$ $\left\{ \right.$

Decay angular distributions Docay angular dictributions **Decay angular upur** $\overline{3}$ First, we present the ! *^K*⁺*K* ² decay angular dis-Decay angular distributions $E1: 1.985 < E_x < 2.185 GeV, E2: 2.185 < E_x < 2.385 GeV$ First, we present the ! *^K*⁺*K* ² decay angular dis-**Decay angular distributions** First, we present the ! *^K*⁺*K* ² decay angular dis-Decay angular distributions at formal and the contract of E1: 1.985<Eγ<2.185 GeV, E2: 2.185<Eγ<2.385 GeV

Comparison of SDME with p, d data

- Natural parity exchange Pomeron exchange dominates.
- 10~13% deviation from pure natural parity exchange
- A) Contribution of unnatural parity exchange? $(f_1, J^{PC}=1^{++})$? Due to the heavy mass, it is expected to be suppressed…
- B) Violation of the assumption of helicity-conservation?
- Non zero ρ^0 ₁₋₁ also indicates spin-double-flip amplitude (PRC67,065205)
- Exchange of tensor particle?
- Theoretical inputs and advices are welcome!

Results of the *dσ/dt* measurements $\ddot{}$

No significant energy dependence was observed.

$$
\frac{d\sigma}{d\tilde{t}} = N_0 \exp(-b\tilde{t})
$$

Weighted mean of the t -slope

 23.81 ± 0.95 (stat.)^{+5.15}_{-0.00} (syst.)

 \rightarrow Consistent with b (yp \rightarrow ϕ p) + b (Form Factor) $= 3.3 + 22 = 25.3$ (GeV⁻²).

dσ/dt at tmin (*k/k*)² ² a kinematical factor due to a finite mass of - ³ mesons, *k* and *k* 3-momenta of the incident photon and $-$ overall center-of-mass frame, $-$

seen (2.7s). Æ *It may suggest*

LEPS II

Beam asymmetry (Σ) for η-meson photoproduction

LEPS II facility

Experimental setups @ LEPS II

BGOegg setup

- BGOegg E.M. Calorimeter
	- 1320 BGO crystals
	- polar angle 24-146 degrees
- Drift chamber (DC), forward time of flight (TOF) counters
- Physics data taking from 2014.
- η-meson measurement in this talk

BGOegg

Solenoid spectrometer

- 0.9 T solenoid magnet
- Time Projection Chamber, DC, TOF counters, barrel photon counters.
- First commissioning run in 2016.

Motivation

η meson photoproduction

- Isospin = $0 \rightarrow$ No coupling with Δ
- large strangeness component
	- Stronger coupling of N^{*} to η than to pion may reveal strangeness content in N*. (ex. N(1535))

Analysis for yield estimation

Preliminary results

Preliminary results

Belle

Production rates of hyperons and charmed baryons from e^+e^- annihilation near $\Upsilon(4S)$

Baryon production rates in e+e- collision

$e^+e^- \rightarrow \gamma^* \rightarrow qq \rightarrow Haronization$

- $ex) e^+e^- \rightarrow \gamma^* \rightarrow \Lambda +$ anything
	- not $e^+e^- \rightarrow \gamma^* \rightarrow \Lambda +$ anti- Λ

 $\frac{\sigma_{had}(2J+1)}{\sigma_{had}(2J+1)} \propto \exp(-\alpha m_{had})$ \bullet

Relativistic-string model

S.B. Chun, PLB 308(1993)153

- Diquark is important to explain high
baryon rates
- l Higher rates for Λ and Λ(1520) in ARGUS and LEP.
	- Feed down is subtracted?
	- Large error in ARGUS results.
- l J=0, light (ud) diquark in Λ?
	- l R.L. Jaffe, Phys.Rept.409,1 (2005)
	- A. Selem, F. Wilczek, hep-ph/0602128

Diquark structure in hadrons

- **.** Color magnetic interaction
	- α $\lambda^a(i)$ **.** Strong attraction in spin 0 flavor 0 channel
		- **.** "Good" diquark
- **.** Structure of Λ, Σ hyperons

 $S=1$ [ud] "bad" diquark

2

 $\lambda^a(j)$

2

 $\vec{\sigma}(i) \cdot \vec{\sigma}(j)$

 $m_i m_j$

Diquark structure in hadrons

- **.** Color magnetic interaction
	- α $\lambda^a(i)$ **.** Strong attraction in spin 0 flavor 0 channel
		- **.** "Good" diquark
- Structure of $Λ_{c}$, $Σ_{c}$ baryons

 $S=1$ [ud] "bad" diquark

2

 $\lambda^a(j)$

2

 $\vec{\sigma}(i) \cdot \vec{\sigma}(j)$

 $m_i m_j$

Belle data

Integrated luminosity

- : 562. fb⁻¹ @ on Y(4S) resonance data for charmed baryons $(\sqrt{s} = 10.58 \text{ GeV})$
- : 79.3 fb⁻¹ @ continuum data for hyperons, charmed baryons $(\sqrt{s} = 10.52 \text{ GeV})$

Mass spectra for hyperons 3

Mass spectra for charmed baryons 5 0.3 0.31 0.32 0.33 0.34 0.35 0.36 0.37 **π γ υπο** i
I \overline{A}

0.3 0.4 "Inclusive" cross sections vs. xp 0.3 0.4 0.075 0.03

 $(M, p: mass and CM mon)$ **0.1** α hadron scaled momentum (x_p). $\alpha_p = p/\sqrt{s/4 - M^2}$ (M, p : mass and CM momentum) "Inclusive" cross sections (including feed-down) are obtained⁸as a function of (X_p) . $X_p = p / \sqrt{\frac{s}{4}} - 1$ **detailed to the contract of t** $\left(\begin{matrix} \text{IVI}, \text{P} \end{matrix}\right)$. **Inass and C**IVI mon *<u>um</u>*

0.3 0.4 "Inclusive" cross sections vs. xp 0.3 0.4 0.075 0.03

 $(M, p: mass and CM mon)$ **0.1** α hadron scaled momentum (x_p). $\alpha_p = p/\sqrt{s/4 - M^2}$ (M, p : mass and CM momentum) "Inclusive" cross sections (including feed-down) are obtained⁸as a function of (X_p) . $X_p = p / \sqrt{\frac{s}{4}} - 1$ **detailed to the contract of t** $\left(\begin{matrix} \text{IVI}, \text{P} \end{matrix}\right)$. **Inass and C**IVI mon *<u>um</u>*

"Inclusive" cross sections vs. xp 0.1 0.01 0.15 0.01 0.015 0.01 0.015 0.01

the reconstruction efficiency due to the MC statistics. The MC statistics θ

36

shifted slightly to the left for clarity. The error bars include the statistical uncertainties of $\mathbf r$

"Inclusive" cross sections vs. xp 0.1 0.01 0.15 0.01 0.015 0.01 0.015 0.01

37

Results of hyperons \overline{D}_{A} **THESHIPS C**

● Subtract feed down from heavier states;

- **δ68% of inclusive Λ**
- **6** 17% of inclusive Σ^0
- \bullet 25% of inclusive \wedge l 25% of inclusive Λ(1520)
- **65% of inclusive Σ(1644)**
- 2404 cross are smaller than the smaller \bullet 8% of inclusive $\Sigma(1385)^+$
- e 24% of inclusive = l 24% of inclusive Ξ-

Results of charmed baryons

- Subtract feed-down
	- 52% of inclusive Λ_c^+
	- 16% of inclusive $\Sigma_c{}^0$

Results of charmed baryons Desults of ch of production cross section cross section and production cross section and production cross section and product
Section and production cross section conductions of 20 per 20 *conductions* of Che cross section for the *S* = −3 hyperon, Ω[−] ⁶³⁰ , shows further **Result** ϵ of charmond hamsens **s or charmed baryons** sections cross section for the *S* = −3 hyperon, Ω[−] ⁶³⁰ , shows further **1 Re** ϵ **suits of charmed baryons** of α

• Assuming that a c-quark picks up a diquark from vacuum, ("tunnel effect" of diquark and anti-diquark) **Exercise 3 Assuming that a c-**■ Assuming that a *c*- \mathbf{A} α that a c-quark picks up a diquark from rameters *a* c-quark picks up a diquark from that a c-quark picks up a diquark from the pro- \mathcal{L} ● A a by Belle II $\frac{1}{2}$ $\$ raming that a c-quark picks up a diquark from server with the pro-

 $\sigma \propto \exp(-\pi \mu^2/\kappa) \hspace{1em} \mu$: diquark mass
 κ : gluonic string B. Andersson et al., Phys. Scripta. 32, 574 (1985) κ: gluonic string tension σ of orpel $\pi r^2/r$ $\alpha \propto \exp(-n\mu/\hbar)$ resonances is proportional to exp(−π*µ*² κ *και το επιλ*ογικό της και το προσφαιρισμό της προϊόνης της προϊόνης της προϊόνης της προϊόνης της προϊόνης
Γεγονότατα της προϊόνης της προ ⁶⁹⁶), and *µ* is e mass difference of the mass $\frac{1}{2}$ $m(ud_1)^2 - m(ud_0)^2$ (O pic $= (8.2 700^2$ than but consistent with the value of 100^2 ⁴⁹⁰² [−] ⁴²⁰² = 6*.*⁴ [×] ¹⁰⁴ (MeV/*c*²)² $707 - 420^{\circ} =$ 702 ment support support the B. Andersson et al., Ph $\sigma \propto \text{exp}(-\pi u^2/\kappa)$ and the three three terms for a diquark mass charged states, and assume that the *C* π α π decay modes with the *c* π α is tentatively assigned as *J^P* = 3*/*2[−] ⁶³⁸ , so we use a spin of $m(ua_1)$ [−] **mass energy** energy of the mass of the m de fan de production rates of charm quarks be-
Britannich rates of charm quarks be-⁶⁴⁴ come consistent with up quarks. Indeed, near the Υ(4*S*) the production cross section cross section cross section containing tension containing tension containing tension **e** and 0 diquarks and 250 × 2502 (MeV20 $\begin{pmatrix} 9 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$ $d(ud_0)^2$ and d_0 and d_1 d_2 d_3 n $i = (8.2 \pm 0.8) \times 10^4 \text{ (MeV/}c^2)^2$ $1^2 - 420^2 = 6.4 \times 10^4$ (MeV/ c^2)² *420* = 6.1 × 10 (Me v/*c*)
2002 = 6.4 × 104 (Me v/*c*)
2009 = 6.4 × 104 (Me v/c)2 33011 GC dit, Tity3. HGDC $37, 91$ (1909) ref. B. Andersson et al., Phys. Rept. 97, 31 (1983) Mass difference of spin-1 and 0 diquarks charged states, and assume that the Λ⁺ ⁶³⁶ *^c* π decay mode $\overline{\mathsf{R}}$ is tentatively assigned as *J^P* = 3*/*2[−] ⁶³⁸ , so we use a spin of \mathcal{L} ef. ⁶⁴⁴ come consistent with up quarks. Indeed, near the Υ(4*S*) α by α probability of the tunnel effect of a diquark mass of α $\sigma \propto \exp(-\pi \mu^2/\kappa)$ *k*: gluonic string tension κ το εκπειρ_μ και 2502 (MeV22).
Ω 2502 (MeV22000 of orain 1 oral 0 diamonks) ⁶⁹⁶), and *µ* is lass difference of spin-1 and 0 diquarks. The obtained mass \sim $\ln(ud_1)^2 - m(ud_0)^2$ $-$ (0.2 \pm 0.0) \land 10 (IVIC V/C) $490^2 - 420^2 = 6.4 \times 10^4 \text{ (MeV/}c^2)^2$

⁷⁰³ tion mechanism of charmed baryons and a spin-0 diquark component of the Λ⁺ ⁷⁰⁴ *^c* ground state and low-lying excited energy section of the production of the production of the production of the *s*ection \mathcal{S} slightly larger but consistent with diquark masses in reference energy section of the production of the production of the production of the *prod*uction of the *c*hildren of the $\mathbf{S}^{(4)}$ ⁷⁰³ tion mechanism of charmed baryons and a spin-0 diquark ightly larger but consistent with diquark masses in re

- **•** Support diquark structure in ground and low-lying Λ_α, Σ_α barvo al., PRD92 114029 (2015) • Support diquark structure in ground and low-lying Λ_c , Σ_c baryons T. Yoshida et \bullet Su $al.,$
- P_{raduc} **e** Pr

l Production rates can be a top study the structure of hadrons

I imething unexpected mparson of Λ , Σ , Λ (1405)…)

Summary

- LEPS: coherent φ-meson photoproduction from ⁴He
	- Isospin=0 and spin=0 target→No pseudo-scaler exchange
	- SDM elements exhibit
		- no helicity single-filp amplitude,
		- natural parity exchange dominance,
		- 10-13% discrepancies from full natural parity ex. may suggest axialvector ex. or double-helicity-flip amplitude (ex. of tensor object)
	- E_γ dependence of dσ/dt at t=t_{min} show monotonic increase
		- 2.7σ deviation near $E_y = 2.2$ GeV
- LEPS2: beam asymmetry (Σ) for η -meson
	- Energy range up to $\sqrt{s}=2.32$ GeV
	- Polar angular distribution changes from $\sqrt{s}=1.92$ GeV,
- Belle: production rates of hyperons and charmed baryons
	- 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