The Λ_c^+ semi-leptonic and inclusive decay at BESIII

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(on behalf of BESIII collaboration)

IHEP

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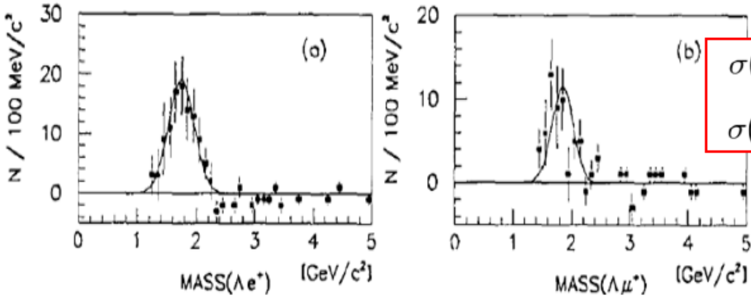
Content

- Λ_c^+ semi-leptonic decay: $\Lambda_c^+ \to \Lambda l^+ \nu_l$
- $\Lambda_c^+ \to e^+ X$
- Λ_c^+ inclusive decay: $\Lambda_c^+ \to \Lambda + X$
- Summary and

History of Λ_c^+ semi-leptonic decay

- **In 1991, ARGUS reported the first measurement of $\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ with 477 pb^{-1} $\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(4S)$ data**

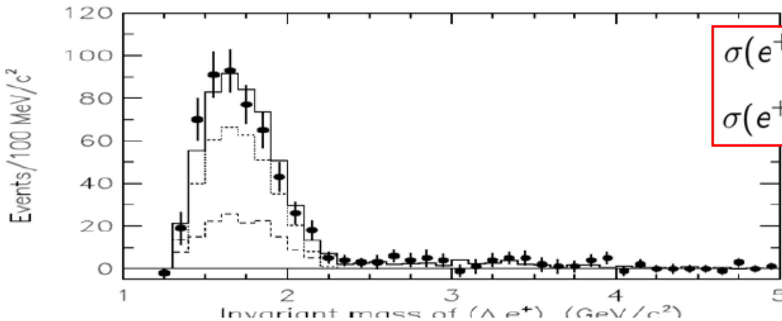


$$\sigma(e^+e^- \rightarrow \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \rightarrow \Lambda e^+ X) = 4.20 \pm 1.28 \pm 0.71 \text{ pb}$$

$$\sigma(e^+e^- \rightarrow \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \rightarrow \Lambda \mu^+ X) = 3.91 \pm 2.02 \pm 0.90 \text{ pb}$$

Phys. Lett. B 269, 234 (1991).

- **In 1994, CLEO performed same measurement with 1.6 fb^{-1} $\Upsilon(4S)$ data**



$$\sigma(e^+e^- \rightarrow \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \rightarrow \Lambda e^+ X) = 4.87 \pm 0.28 \pm 0.69 \text{ pb}$$

$$\sigma(e^+e^- \rightarrow \Lambda_c^+ X) \cdot \mathrm{BR}(\Lambda_c^+ \rightarrow \Lambda \mu^+ X) = 4.43 \pm 0.51 \pm 0.64 \text{ pb}$$

Phys. Lett. B 323, 219 (1994).

- **Based on above two measurements , PDG extracts BF for $\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ with $\tau(\Lambda_c^+)$ and the assumption of form factors**

$\Lambda \ell^+ \nu_\ell$	[r]	(2.8 ± 0.4) %
$\Lambda e^+ \nu_e$		(2.9 ± 0.5) %
$\Lambda \mu^+ \nu_\mu$		(2.7 ± 0.6) %

Not a direct measurement!

Theoretical calculations

Model &Experiment	Br^{exp} [%]	References
SU(4) symmetry limit	9.2	M. Avila-Aoki et al [PRD40, 2944 (1989)]
Non-relativistic quark model	2.6	Perez-Marcial et al [PRD40, 2955 (1989)]
MIT bag model [MBM]	1.9	Perez-Marcial et al [PRD40, 2955 (1989)]
Relativistic spectator Model	4.4	F. Hussain et al [ZPC51, 607 (1991)]
Spectator quark model	1.96	Robert Singleton, Jr. [PRD43, 2939(1991)]
Quark confinement Model	5.62	G. V. Efimov et al [ZPC52, 149 (1991)]
Non-relativistic quark model	2.15	A. Garcia et al [PRD45, 3266 (1992)]
Non-relativistic quark model	1.42	H. Y. Cheng et al [PRD53, 1457 (1995)]
QCD Sum Rule	3.0 ± 0.9	H. G. Dosch et al [PLB431, 173 (1998)]
QCD Sum Rule	2.6 ± 0.4	R. S. Marques de Carvalho et al [PRD60, 034009 (1999)]
QCD Sum Rule	5.8 ± 1.5	
HOSR	4.72	M. Pervin et al [PRC72, 035201 (2005)]
HONR	4.2	
STSR	2.22	
STNR	1.58	
LCSRs	3.0 ± 0.3 (CZ-type) 2.0 ± 0.3(Ioffe-type)	Y. L. Liu, M.Q. Huang and D. W. Wang [PRD80, 074011 (2009)]
Convariant confined quark model	2.78	Thomas Gutsche et al [PRD93, 034008(2016)]
relativistic quark model	3.25	R. N. Faustov, V. O. Galkina, Eur. Phys. J. C (2016) 76:628
Lattice QCD	$3.80\pm0.19_{LQCD}\pm0.11_{\tau\Lambda c}$	Stefan Meinel, PRL118,082001 (2017)

Data samples at BESIII

In 2014, BESIII collected data above Λ_c pair threshold and run machine at 4.599 GeV with excellent performance.

Energy (GeV)	Luminosity (pb^{-1})
4.575	~48
4.580	~8.5
4.590	~8.1
4.599	~567

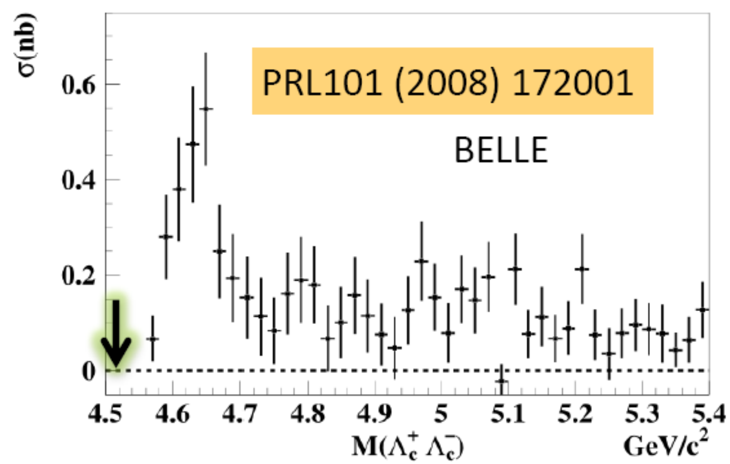
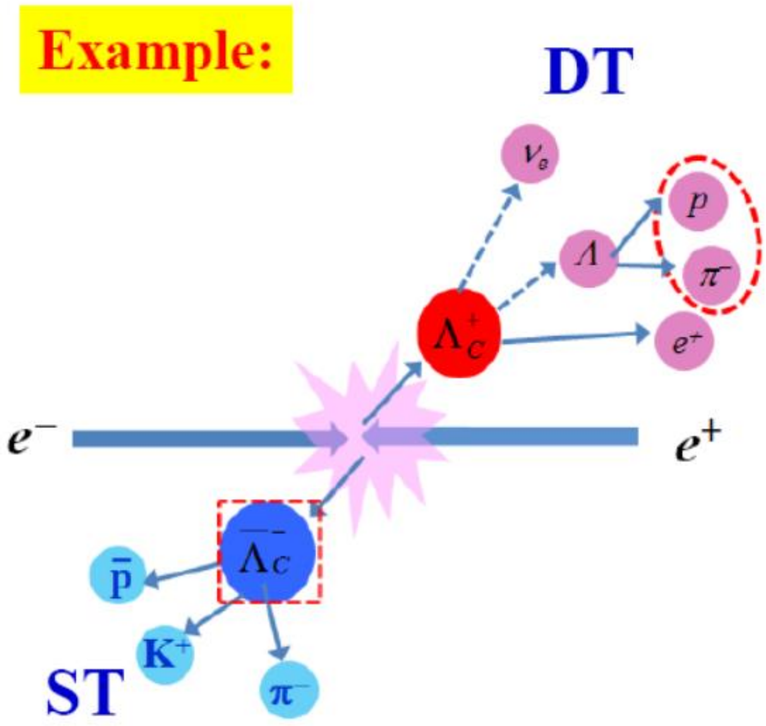


FIG. 4: The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

In the future, it is possible that BESIII can collect Λ_c data at high energies, for example 4.64 GeV or more high energies.

It is time to systematically study the decay property of Λ_c at BESIII.

Analysis Technique



✓Single Tags (ST)

$$M_{\rm BC} = \sqrt{E_{\rm beam}^2 - |\vec{p}_{\bar{\Lambda}_c^-}|^2}$$

✓Double Tags (DT)

$$U_{\rm miss} = E_{\rm miss} - c|\vec{p}_{\rm miss}|$$

✓Branching Fraction (BF)

$$\mathcal{B}_{\rm SL} = \frac{N^{\rm semi}}{N^{\rm tag} \times \epsilon}$$

Clean sample of ST charmed baryons can be fully reconstructed by hadronic decays with large BFs. Based on this, one can access to absolute BFs and dynamics in the decays.

Singly tagged Λ_c^+ baryons

The singly tagged $\bar{\Lambda}_c^-$ baryons are reconstructed by:

- $\Lambda_c^- \to \bar{p}K_S^0$, $\Lambda_c^- \to \bar{p}K^+\pi^-$
- $\Lambda_c^- \to \bar{p}K_S^0\pi^0$, $\Lambda_c^- \to \bar{p}K^+\pi^-\pi^0$,
- $\Lambda_c^- \to \bar{p}K_S^0\pi^+\pi^-$, $\Lambda_c^- \to \bar{\Lambda}\pi^-$,
- $\Lambda_c^- \to \bar{\Lambda}\pi^-\pi^0$, $\Lambda_c^- \to \bar{\Lambda}\pi^-\pi^+\pi^-$,
- $\Lambda_c^- \to \bar{\Sigma}^0\pi^-$, $\Lambda_c^- \to \bar{\Sigma}^-\pi^0$ and $\Lambda_c^- \to \bar{\Sigma}^-\pi^+\pi^-$,

with

- $K_S^0 \to \pi^+\pi^-$,
- $\bar{\Lambda} \to \bar{p}\pi^+$,
- $\bar{\Sigma}^0 \to \gamma\bar{\Lambda}$ with $\bar{\Lambda} \to \bar{p}\pi^+$,
- $\bar{\Sigma}^- \to \bar{\Lambda}\pi^-$,
- $\pi^0 \to \gamma\gamma$.

PDG2017

Mode	BF (%)	Mode	BF (%)
$\bar{p}K_S^0$	1.58±0.08	$\bar{\Lambda}\pi^-\pi^0$	7.1±0.4
$\bar{p}K^+\pi^-$	6.35±0.33	$\bar{\Lambda}\pi^-\pi^+\pi^-$	3.7±0.4
$\bar{p}K_S^0\pi^0$	1.99±0.13	$\bar{\Sigma}^0\pi^-$	1.29±0.07
$\bar{p}K_S^0\pi^+\pi^-$	1.66±0.12	$\bar{\Sigma}^-\pi^0$	1.24±0.10
$\bar{p}K^+\pi^-\pi^0$	4.9±0.4	$\bar{\Sigma}^-\pi^+\pi^-$	4.57±0.29
$\bar{\Lambda}\pi^-$	1.30±0.07	Total	~36%

Singly tagged Λ_c^+ yields

Phys. Rev. Lett 115, 221805 (2015)

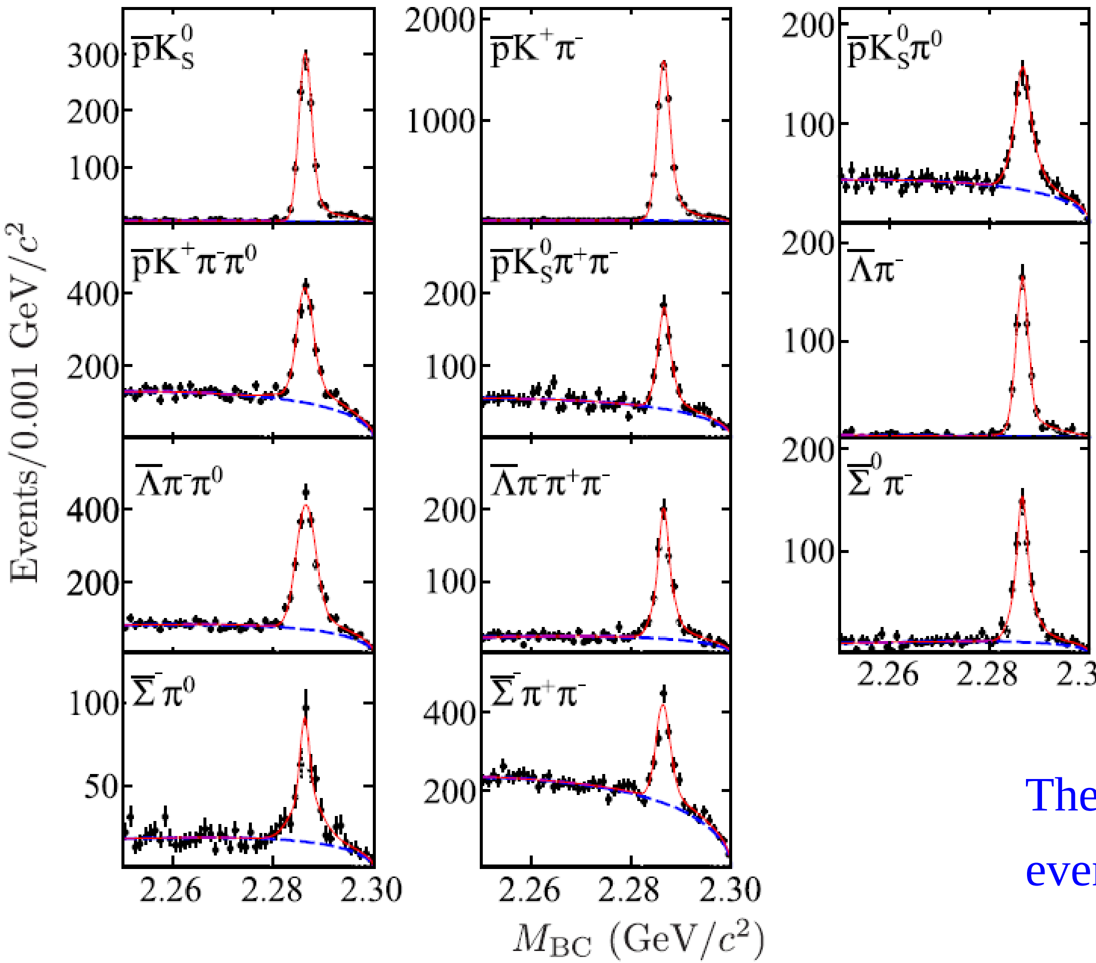
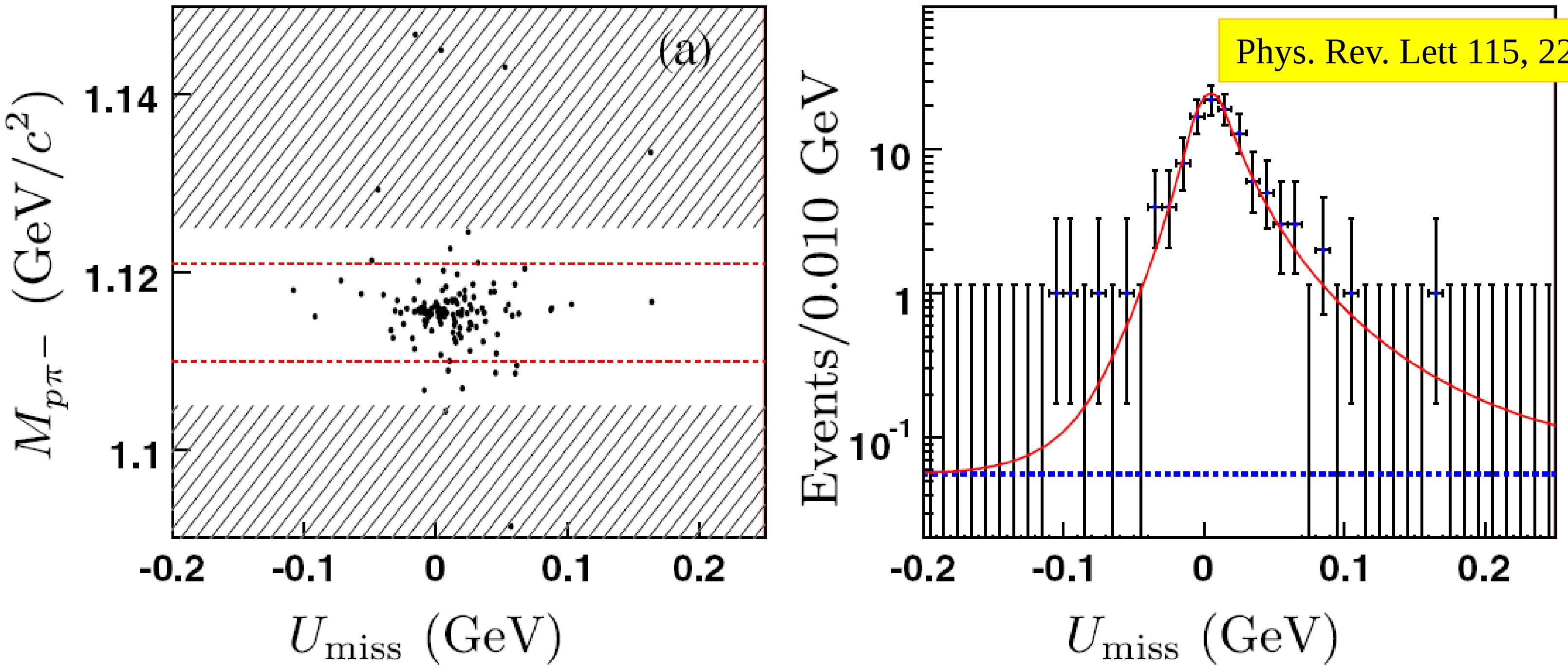


TABLE I. ΔE requirements and ST yields $N_{\bar{\Lambda}_c^-}$ in data.

Mode	ΔE (GeV)	$N_{\bar{\Lambda}_c^-}$
$\bar{p}K_S^0$	[−0.025, 0.028]	1066 ± 33
$\bar{p}K^+\pi^-$	[−0.019, 0.023]	5692 ± 88
$\bar{p}K_S^0\pi^0$	[−0.035, 0.049]	593 ± 41
$\bar{p}K^+\pi^-\pi^0$	[−0.044, 0.052]	1547 ± 61
$\bar{p}K_S^0\pi^+\pi^-$	[−0.029, 0.032]	516 ± 34
$\bar{\Lambda}\pi^-$	[−0.033, 0.035]	593 ± 25
$\bar{\Lambda}\pi^-\pi^0$	[−0.037, 0.052]	1864 ± 56
$\bar{\Lambda}\pi^-\pi^+\pi^-$	[−0.028, 0.030]	674 ± 36
$\bar{\Sigma}^0\pi^-$	[−0.029, 0.032]	532 ± 30
$\bar{\Sigma}^-\pi^0$	[−0.038, 0.062]	329 ± 28
$\bar{\Sigma}^-\pi^+\pi^-$	[−0.049, 0.054]	1009 ± 57

The total ST Λ_c^+ yield is 14415±159 events with 11 ST modes.

$\Lambda_c^+ \to \Lambda e^+ \nu_e$ decays



Phys. Rev. Lett 115, 221805 (2015)

- Theoretical calculation on the BF: 1.4% ~ 9.2%;
- Experimental measurements: (2.1±0.6)% (PDG2014:) → $Br[\Lambda_c^+ \to pK^-\pi^+] = (6.84^{+0.32}_{-0.40})\%$ → (2.9±0.5)% (PDG2015);
- Our measurement: $Br[\Lambda_c^+ \to \Lambda e^+ \nu_e] = (3.63 \pm 0.38 \pm 0.20)\%$.

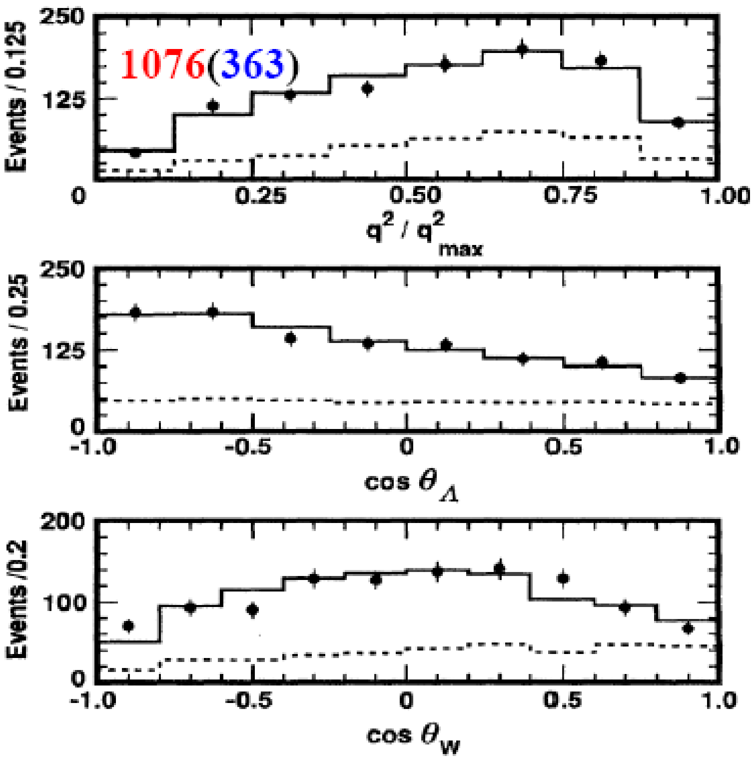
First absolute measurement

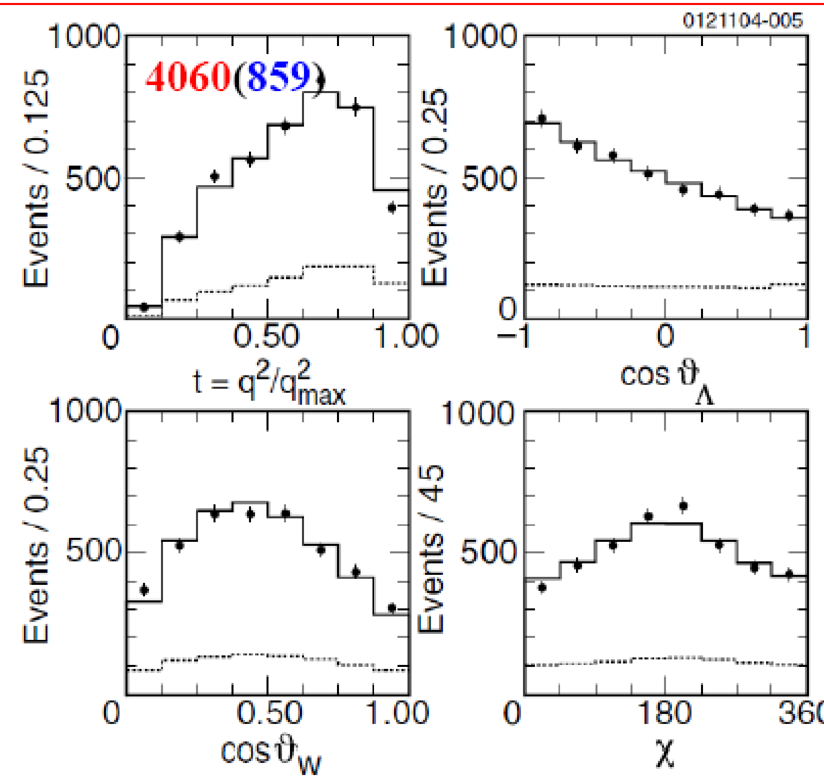
Important to test and calibrate the LQCD calculations.

Form factors in $\Lambda_c^+ \to \Lambda e^+ \nu_e$

Previous Measurements.

$$\Gamma_S = \frac{d\Gamma}{dq^2 d\cos\Theta_W d\cos\Theta_\Lambda} = B(\Lambda \to p\pi)\,\frac{1}{2}\,\frac{G_F^2}{(2\pi)^4}|V_{cs}|^2 \frac{q^2 P}{24 M_{\Lambda_c}^2}$$
$$\times \{\tfrac{3}{8}(1 - \cos\Theta_W)^2 |H_{(1/2)1}|^2 (1 + \alpha_\Lambda \cos\Theta_\Lambda) + \tfrac{3}{8}(1 + \cos\Theta_W)^2 |H_{(-1/2)-1}|^2 (1 - \alpha_\Lambda \cos\Theta_\Lambda)$$
$$+ \tfrac{3}{4}\sin^2\Theta_W [|H_{(1/2)0}|^2 (1 + \alpha_\Lambda \cos\Theta_\Lambda) + |H_{(-1/2)0}|^2 (1 - \alpha_\Lambda \cos\Theta_\Lambda)]\},$$

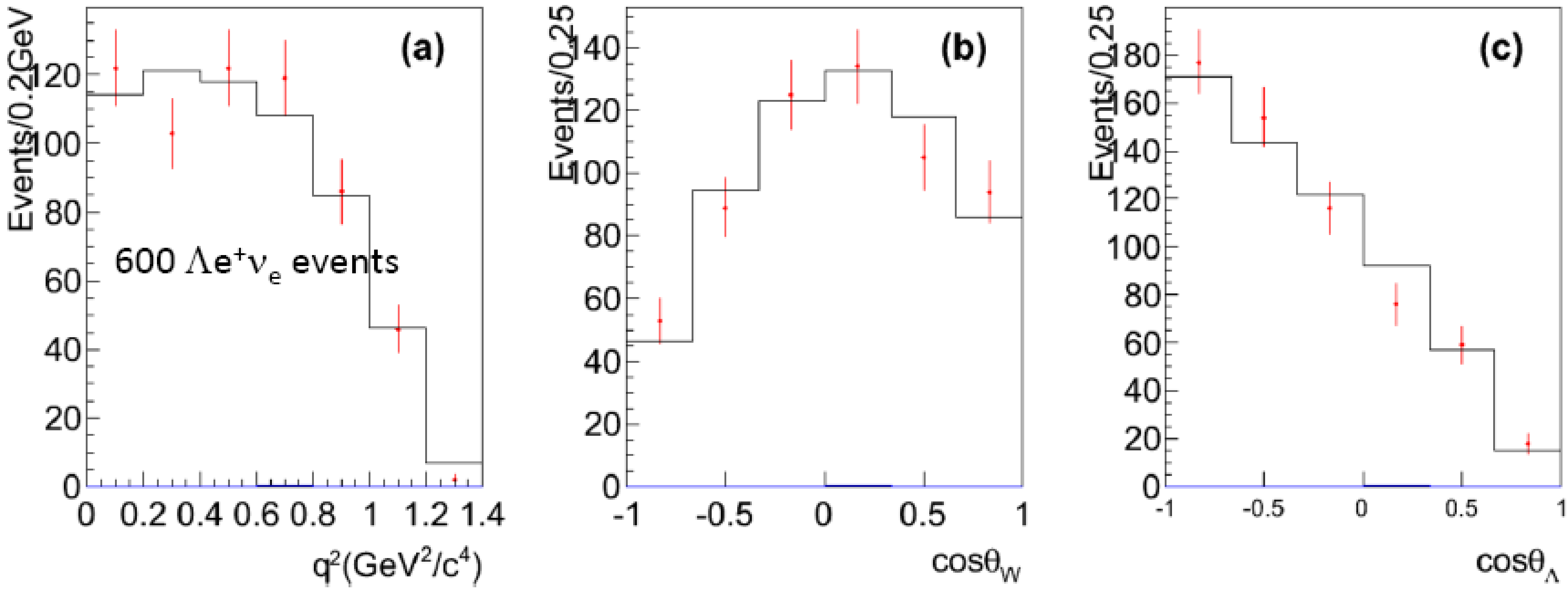




CLEO Collaboration, PRL75, 624(1995); CLEO Collaboration, PRL94, 191801(2005);

Form factors in $\Lambda_c^+ \to \Lambda e^+ \nu_e$

- MC simulation based on 3fb[-1] data @ 4.6 GeV.



✓ Based on MC simulation, we obtain f_2/f_1=-0.31±0.08(25%), input: -0.31;

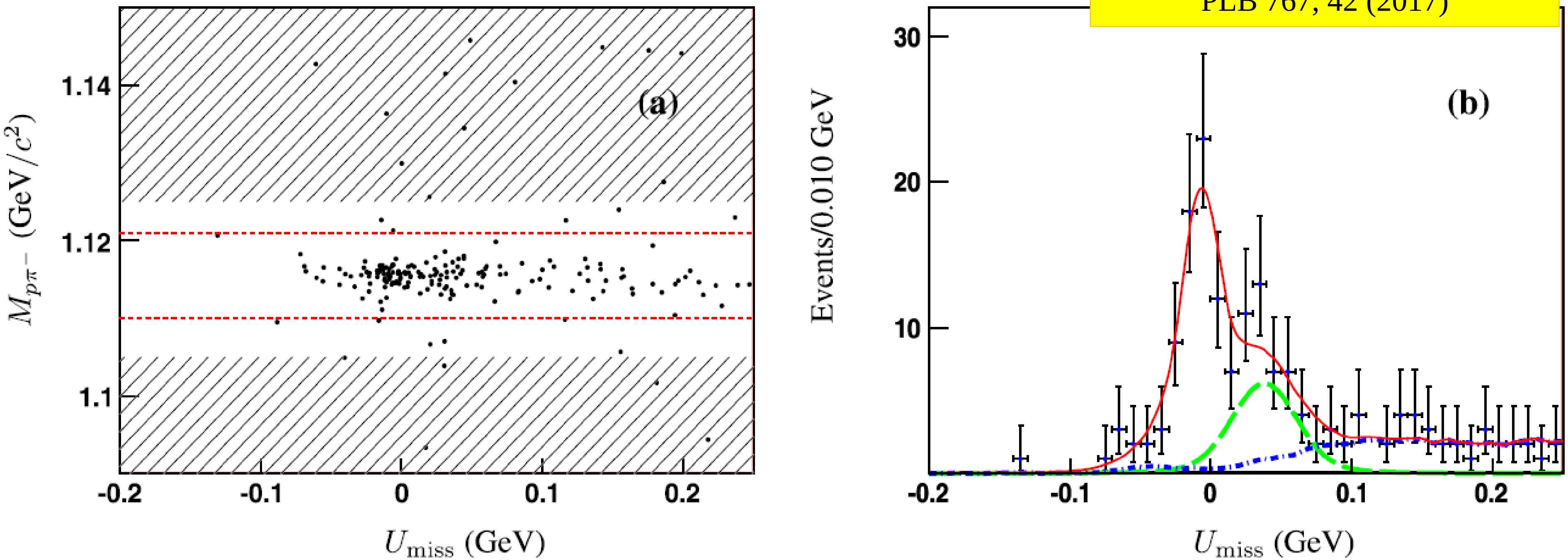
✓ CLEO measurements: f_2/f_1=-0.25±0.14 ±0.08 (64%) 1995 年结果;

✓ CLEO measurements: f_2/f_1=-0.31±0.05±0.04 (21%) 2005 年结果;

It seems that we can achieve a competitive precision for f_2/f_1 by combining the electron and muon channels with 3 fb[-1] data @ 4.6 GeV at BESIII.

$\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$ decays

PLB 767, 42 (2017)



- Theoretical calculation on the BF: 1.4% ~ 9.2%;
- Our measurement: $Br[\Lambda_c^+ \to \Lambda\mu^+\nu_\mu] = (3.49 \pm 0.46 \pm 0.26)\%$;

First absolute measurement

- $\frac{\Gamma[\Lambda_c^+ \to \Lambda\mu^+\nu_\mu]}{\Gamma[\Lambda_c^+ \to \Lambda e^+\nu_e]} = 0.96 \pm 0.16 \pm 0.04$.

Updated theoretical calculation

$\Lambda_c \to \Lambda \ell^+ \nu_\ell$ form factors and decay rates from lattice QCD with physical quark masses

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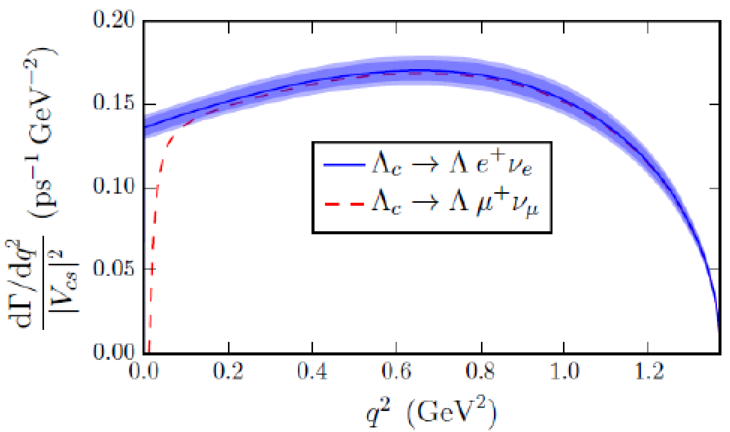
Department of Physics, University of Arizona, Tucson, AZ 85721, USA and
RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973, USA
(Dated: November 29, 2016)

Phys. Rev. Lett 118, 082001 (2017)



$$\mathcal{B}(\Lambda_c \to \Lambda \ell^+ \nu_\ell) = \begin{cases} 0.0363(38)(20), & \ell = e, \\ 0.0349(46)(27), & \ell = \mu. \end{cases}$$

$$\mathcal{B}(\Lambda_c \to \Lambda \ell^+ \nu_\ell) = \begin{cases} 0.0380(19)_{\rm LQCD}(11)_{\tau_{\Lambda_c}}, & \ell = e, \\ 0.0369(19)_{\rm LQCD}(11)_{\tau_{\Lambda_c}}, & \ell = \mu, \end{cases}$$

Previous determinations of $|V_{cs}|$

$$|V_{cs}| = \begin{cases} 1.008(5)(16) & \text{from } D_s \to \ell^+ \nu_\ell \text{ [5, 6]}, \\ 0.975(25)(7) & \text{from } D \to K \ell^+ \nu_\ell \text{ [6, 7]}, \\ 0.97344(15) & \text{indirect, CKM unitarity [8]}. \end{cases}$$

基于BESIII测定的$\Lambda_c^+ \to \Lambda l^+ \nu_l$的测量结果

$$|V_{cs}| = \begin{cases} 0.951(24)_{\rm LQCD}(14)_{\tau_{\Lambda_c}}(56)_{\mathcal{B}}, & \ell = e, \\ 0.947(24)_{\rm LQCD}(14)_{\tau_{\Lambda_c}}(72)_{\mathcal{B}}, & \ell = \mu, \\ 0.949(24)_{\rm LQCD}(14)_{\tau_{\Lambda_c}}(49)_{\mathcal{B}}, & \ell = e, \mu, \end{cases}$$

$\Lambda_c^+ \to e^+ X$

Ongoing analysis

- **Provide information for Λ_c^+ SL decays**

  $B[\Lambda_c^+ \to \Lambda e^+ \nu_e] = (3.63 \pm 0.38 \pm 0.20)\%$ BESIII

  $B[\Lambda_c^+ \to e + X] = (4.5 \pm 1.7)\%$

- **Test predications for $\Gamma(\Lambda_c^+ \to e+X)/\Gamma(D \to e+X)$**

  实验上： **$\Gamma(\Lambda_c^+ \to e+X)/\Gamma(D \to e+X) = 1.44 \pm 0.54$**

  理论上： Michael Gronau and Jonathan L. Rosner [PRD83, 034025(2011)]

$$\frac{\Gamma(\Lambda_c^+ \to e^+ X)}{\Gamma(D \to e^+ X)} = \left[\frac{M(\Lambda_c^+)}{M(D)}\right]^5 \left[\frac{f(\Lambda_c^+)}{f(D)}\right] = 1.67$$

Decay	M_i (MeV/c^2)	M_f (MeV/c^2)	x	$f(x)$
$D \to \bar{K} \ell^+ \nu_\ell$ [a]	1867.22	495.65	0.07046	0.5971
$D \to \bar{K}^* \ell^+ \nu_\ell$ [a]	1867.22	893.80	0.22913	0.1887
$\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell$	2286.46	1115.68	0.23810	0.1763

where f(x) is the spin-weighted averaged kinematic factor.

Reducing the experimental error is important for testing predictions.

Recent predictions for $\Lambda_c^+ \to ne^+\nu_e$

✓ 为计算$\Lambda_b \to p l^+ \nu_l$ 的形状因子提供信息；

✓ 检验理论预言；

papers	Predictions for $\Lambda_c^+ \to ne^+\nu_e$
K. Azizi et al, PRD80, 096007 (2009) **Light cone QCD sum rule**	**(2.54 ± 0.9) ‰**
T. Gutsche et al., PRD90, 114033 (2016) **Covariant confined quark model**	**0.2%**
Cai-Dian Lü, Wei Wang and Fu-Sheng Yu, Phys. Rev. D 93, 056008 (2016); **SU(3) symmetry**	**(2.93 ± 0.34) ‰** $\mathcal{B}(\Lambda_c \to ne^+\nu_e) = \frac{3}{2}\frac{\lvert V_{cd}\rvert^2}{\lvert V_{cs}\rvert^2}\mathcal{B}(\Lambda_c \to \Lambda e^+\nu_e)$, $\mathcal{B}(\Lambda_c \to n\bar{K}^0 e^+\nu_e) = \mathcal{B}(\Lambda_c \to pK^- e^+\nu_e) \sim \mathcal{O}(10^{-3})$.
R. N. Faustov, V. O. Galkina, Eur. Phys. J. C. 76, 628 (2016); **relativistic quark model**	**0.268%**
Cheng-Fei Li, Yong-Lu Liu, Ke Liu, Chun-Yu Cui, Ming-Qiu Huang, arXiv: 1610.05418 **light-cone QCD sum rules**	**(2.6 ± 0.1) ‰**

□ 实验上测量的困难 1) n; 2) Br[$\Lambda_c^+ \to \Lambda e^+\nu_e$, $\Lambda \to n\pi^0$]=1.3%;

Search for $\Lambda_c^+ \to \Lambda^* l^+ \nu_l$

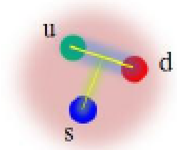
- If Λ_c^+ is J=1/2, it favors the decay $\Lambda_c^+ \to \Lambda l^+ \nu_l$.

Λ_c^+ $I(J^P) = 0(\frac{1}{2}^+)$

J is not well measured; $\frac{1}{2}$ is the quark-model prediction.

Mass $m = 2286.46 \pm 0.14$ MeV
Mean life $\tau = (200 \pm 6) \times 10^{-15}$ s (S = 1.6)
$c\tau = 59.9\ \mu$m

$B[\Lambda_c^+ \to \Lambda^* l^+ \nu_l] << B[\Lambda_c^+ \to \Lambda l^+ \nu_l]$?



suggestive of di-quark model

- **Searching for $\Lambda_c^+ \to \Lambda^* l^+ \nu_l$ is quite important.**

$\Lambda(1405)\ 1/2^-$ $I(J^P) = 0(\frac{1}{2}^-)$

Mass $m = 1405.1^{+1.3}_{-1.0}$ MeV
Full width $\Gamma = 50.5 \pm 2.0$ MeV
Below $\overline{K}N$ threshold

$\Lambda(1405)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma\pi$	100 %	155

$\Lambda(1520)\ 3/2^-$ $I(J^P) = 0(\frac{3}{2}^-)$

Mass $m = 1519.5 \pm 1.0$ MeV [a]
Full width $\Gamma = 15.6 \pm 1.0$ MeV [a]

$\Lambda(1520)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	(45 ±1) %	243
$\Sigma\pi$	(42 ±1) %	268
$\Lambda\pi\pi$	(10 ±1) %	259
$\Sigma\pi\pi$	(0.9 ±0.1) %	169
$\Lambda\gamma$	(0.85 ±0.15) %	350

$\Lambda(1600)\ 1/2^+$ $I(J^P) = 0(\frac{1}{2}^+)$

Mass $m = 1560$ to 1700 (≈ 1600) MeV
Full width $\Gamma = 50$ to 250 (≈ 150) MeV
$p_{beam} = 0.58$ GeV/c $4\pi\lambda^2 = 41.6$ mb

$\Lambda(1600)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	15–30 %	343
$\Sigma\pi$	10–60 %	338

$\Lambda(1670)\ 1/2^-$ $I(J^P) = 0(\frac{1}{2}^-)$

Mass $m = 1660$ to 1680 (≈ 1670) MeV
Full width $\Gamma = 25$ to 50 (≈ 35) MeV
$p_{beam} = 0.74$ GeV/c $4\pi\lambda^2 = 28.5$ mb

$\Lambda(1670)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$N\overline{K}$	20–30 %	414
$\Sigma\pi$	25–55 %	394
[illegible]	[illegible]	[illegible]
$N\overline{K}^*(892)$, S=3/2, D-wave	(5±4) %	†

$\Lambda^* \to pK^-/\Sigma\pi$

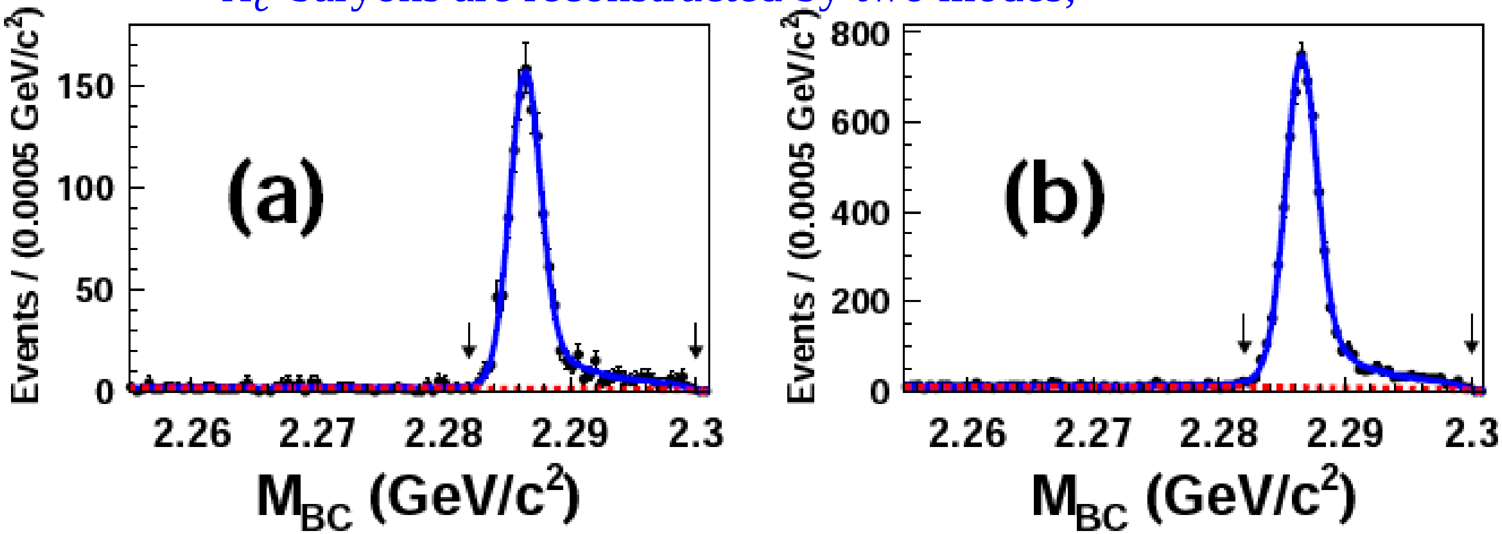
channel	N. Ikeno et al. [PRD93, 14021]	M. Pervin et al [PRC72, 035201]
$\Lambda_c^+ \to \Lambda(1405)\ e^+\nu_e$	2×10^{-5}	0. 6%
$\Lambda_c^+ \to \Lambda(1520)\ e^+\nu_e$	‒‒	0. 1%

Some theories suggested that the weak decay processes are important to clarify the existence and the nature of *Λ(1405). Thus, study of $\Lambda_c^+ \to \Lambda(1405) l^+ \nu_l$* is very important.

Λ_c^+ inclusive decay: $\Lambda_c^+ \to \Lambda + X$

arXiv: 1803. 05706

Double Λ_c^+ tag method is used in this analysis. The singly Λ_c^+ baryons are reconstructed by two modes;



Tag mode i	ΔE (GeV)	$M_{\rm BC}$ (GeV/c^2)	$N_i^{\rm tag}$
$\bar{\Lambda}_c^- \to \bar{p} K_S^0$	$[-0.021, 0.019]$	$[2.282, 2.300]$	1220 ± 37
$\bar{\Lambda}_c^- \to \bar{p} K^+ \pi^-$	$[-0.020, 0.015]$		6088 ± 85

$$N_i^{\rm tag} = 2 \cdot N_{\Lambda_c^+ \bar{\Lambda}_c^-} \cdot \mathcal{B}_i^{\rm tag} \cdot \varepsilon_i^{\rm tag},$$

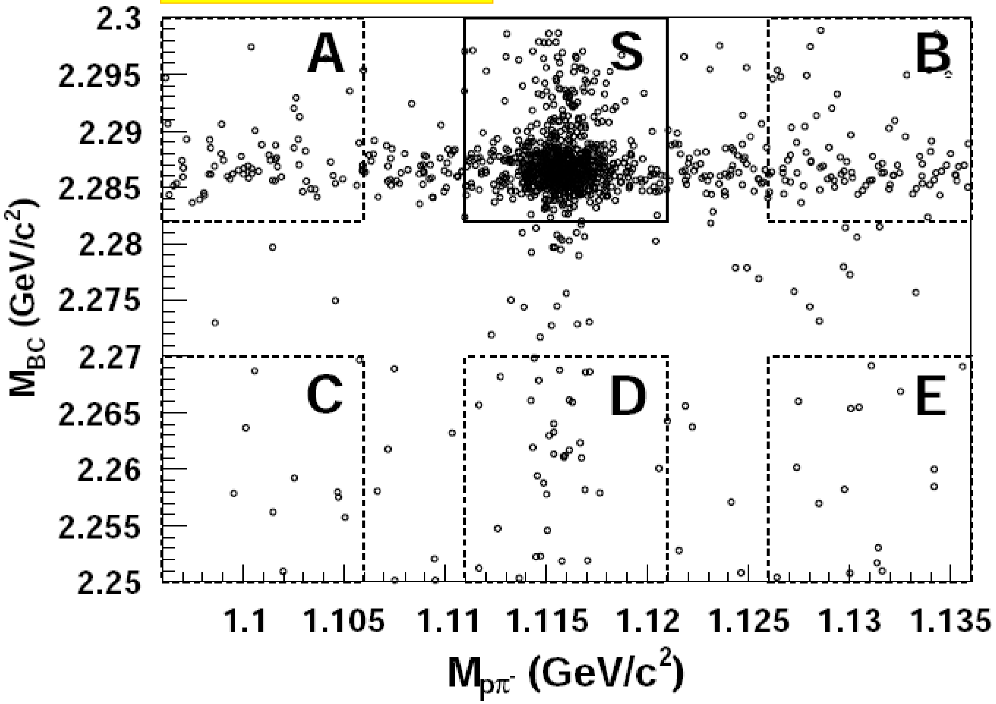
$$N_i^{\rm sig} = 2 \cdot N_{\Lambda_c^+ \bar{\Lambda}_c^-} \cdot \mathcal{B}_i^{\rm tag} \cdot \mathcal{B}^{\rm sig} \cdot \varepsilon_i^{\rm tag} \cdot \varepsilon^{\rm sig},$$

$$\mathcal{B}^{\rm sig} = \frac{(\sum_i N_i^{\rm sig})/\varepsilon^{\rm sig}}{\sum_i N_i^{\rm tag}}.$$

The total ST Λ_c^+ yield is 7308±93 events with two ST modes (14415±159 for 11 modes).

Λ_c^+ inclusive decay: $\Lambda_c^+ \to \Lambda + X$

arXiv: 1803. 05706



$B(\Lambda_c^+ \to \Lambda + X) = (38.2^{+2.8}_{-2.2} \pm 0.8)\%$
PDG2015: $(35 \pm 11)\%$

CP asymmetry in Λ_c^+ decay:

$$\mathcal{A}_{CP} \equiv \frac{\mathcal{B}(\Lambda_c^+ \to \Lambda + X) - \mathcal{B}(\bar{\Lambda}_c^- \to \bar{\Lambda} + X)}{\mathcal{B}(\Lambda_c^+ \to \Lambda + X) + \mathcal{B}(\bar{\Lambda}_c^- \to \bar{\Lambda} + X)}$$

$$= (2.1^{+7.0}_{-6.6} \pm 1.4)\%$$

Counting method to calculate the signal events:

$$N^{\rm sig} = N^{\rm S} - \frac{N^{\rm A} + N^{\rm B}}{2} - f \cdot (N^{\rm D} - \frac{N^{\rm C} + N^{\rm E}}{2}),$$

Discuss with $\Lambda_c^+ \to \Lambda + X$ results

arXiv: 1803. 05706

State	$\mathcal{B}(\%)$	State	$\mathcal{B}(\%)$
$\Lambda\pi^+$	1.29 ± 0.07	$\Sigma^0\pi^+$	1.28 ± 0.07
$\Lambda\pi^+\pi^0$	7.0 ± 0.4	$\Sigma^0\pi^+\pi^0$	3.03 ± 0.23
$\Lambda 3\pi$	6.02 ± 0.48	$\Sigma^0\pi^-2\pi^+$	1.10 ± 0.30
$\Lambda 4\pi$	2.75 ± 1.00	$\Sigma^0\pi^+2\pi^0$	1.10 ± 0.18 (a)
$\Lambda K^+\overline{K}^0$	0.56 ± 0.11	$\Sigma^0 K^+$	0.051 ± 0.008
$\Lambda e^+\nu_e$	3.63 ± 0.43	$\Sigma^0 K^+\pi^0$	0.21 ± 0.06 (b)
$\Lambda\mu^+\nu_\mu$	3.49 ± 0.53	$\Sigma^0 K^0\pi^+$	0.21 ± 0.06 (b)
Total	24.74 ± 1.37	Total	6.98 ± 0.43

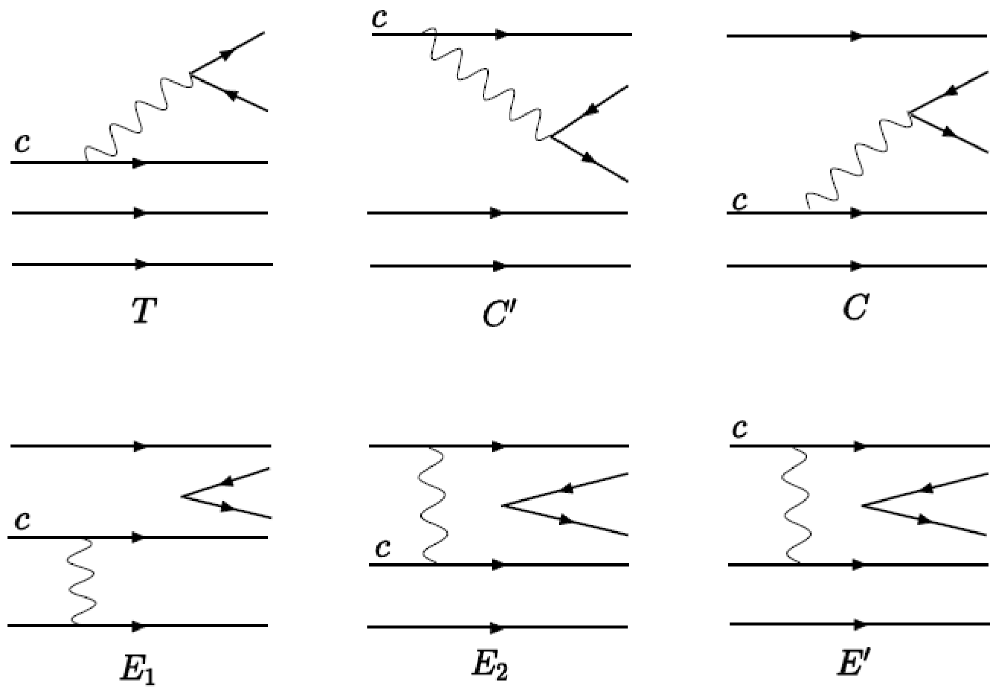
This table lists the BFs with $\Lambda + X$ and $\Sigma^0 + X$. Since $\mathrm{B}(\Sigma^0 \to \gamma\Lambda) = 100\%$, the sum of these totals is $(31.72 \pm 1.44)\%$, a shortfall of 2.4σ.

Possible missing modes: $\Lambda n\pi$ $(n > 4)$ or $\Sigma^0 n\pi$ $(n > 3)$, semi-leptonic decays $\Lambda X l^+\nu_l$.

$\Lambda_c^+ \to \overline{K} + X$

Ongoing analysis

Diagrammatic approach (Chau, HYC, Tseng 96)



Mode	BF (%)	$\overline{\Lambda}\pi^-\pi^0$	BF (%)
$\bar{p}K_S^0$	1.58±0.08	$\overline{\Lambda}\pi^-$	1.30±0.07
$\bar{p}K^+\pi^-$	6.35±0.33	$\overline{\Lambda}\pi^-\pi^0$	7.1±0.4
$\bar{p}K_S^0\pi^0$	1.99±0.13	$\overline{\Lambda}\pi^-\pi^0\pi^0$	--
$\bar{p}K_S^0\pi^+\pi^-$	1.66±0.12	$\overline{\Lambda}\pi^-\pi^+\pi^-$	3.7±0.4
$\bar{p}K^+\pi^-\pi^0$	4.9±0.4	$\overline{\Lambda}\pi^-\pi^0$	

- The $c \to s$ Cabibbo-favored transition dominates the decay of the Λ_c^+ and can be divided into $\Lambda_c^+ \to \Lambda + X$ and $\Lambda_c^+ \to \overline{K} + X$.
- What's the relation between these two inclusive decays?

Summary and Prospect

- BESIII provides important results on Λ_c^+ semi-leptonic and inclusive decay;
- These results are important to the decay property of Λ_c^+;
- More important results are in progress or will be possible at BESIII!

Thank You !