BESIII上Λ_c^+半轻衰变研究

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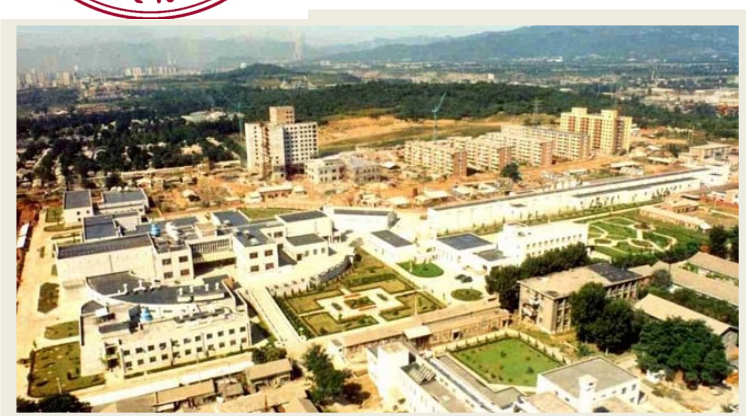
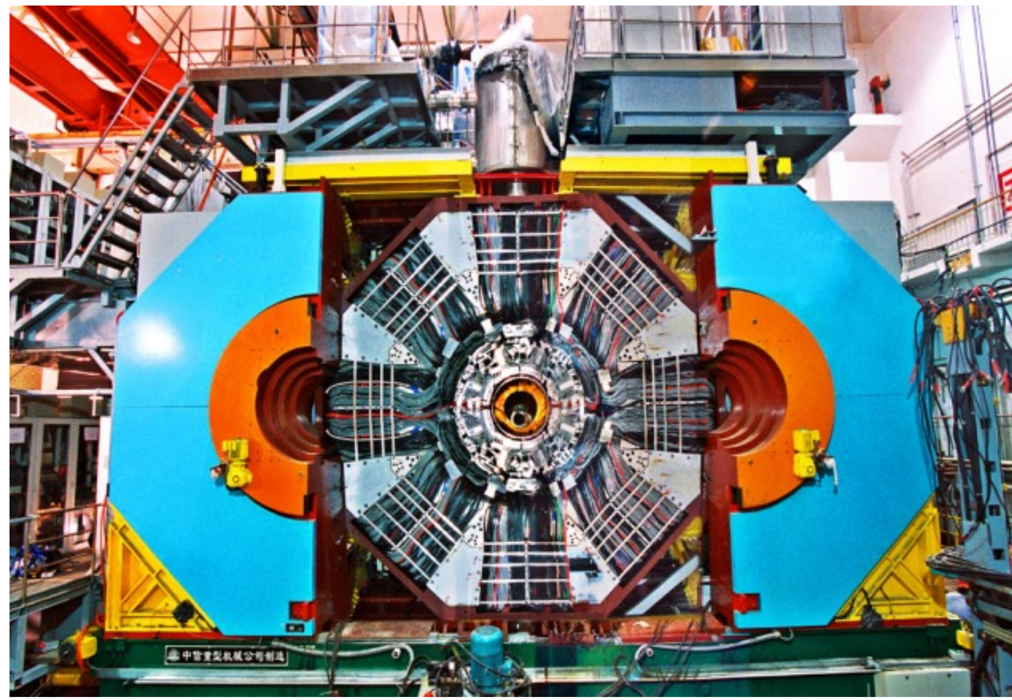




BESIII 粲强子物理研讨会，2023/04/06-2023/04/09，安徽合肥

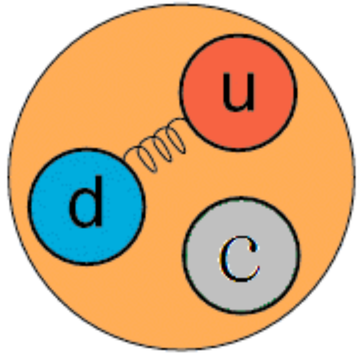
Outline

- Introduction
- Study of Λ_c^+ SL decays at BESIII
- Summary

Λ_c^+ cornerstone of charmed baryon spectroscopy

Quark model picture:

a heavy quark (c) with a unexcited spin-zero diquark (u-d)
Heavy Quark Effective Theory predicts that Λ_c may provide more powerful test on internal dynamics than D/D_s



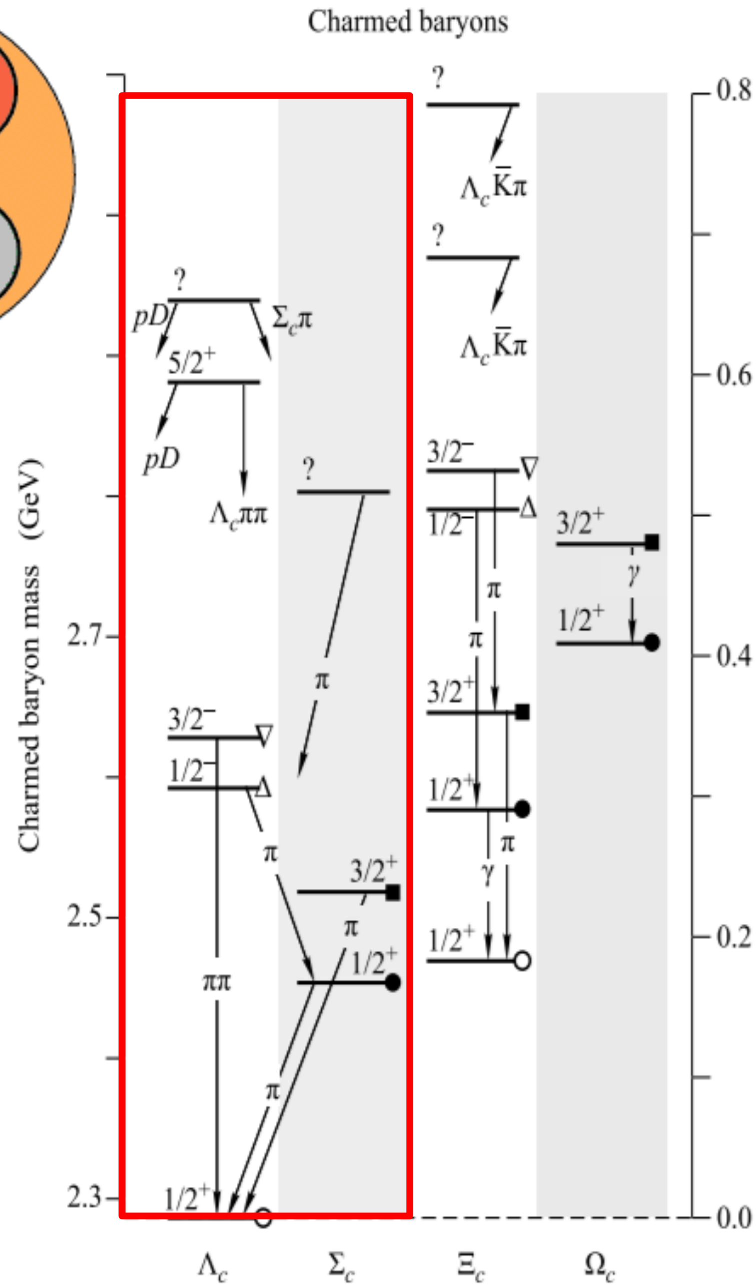
Cornerstone of charmed baryons:

Λ_c^+ is the lightest charmed baryon, most of t
charmed baryons will eventually decay to Λ_c

Essential input for study the decays of b-flavored hadrons involving Λ_c in final state

Status of Λ_c^+ measurement [PDG2015]:

- *poorly understood compared to charm mesons total BF~60%, large uncertainties(>20%)*
- *Relative measurement*
- *No neutron mode has been observed yet.*



Λ_c^+ Measurements [PDG2015]

Λ_c^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	ΔB/B
Hadronic modes with a p: $S=-1$ final states				
$p\overline{K}^0$		(3.21 ± 0.30) %		9.3%
$pK^-\pi^+$		$(6.84^{+0.32}_{-0.40})$ %		5.8%
$p\overline{K}^*(892)^0$	[q]	(2.13 ± 0.30) %		14.1%
$\Delta(1232)^{++}K^-$		(1.18 ± 0.27) %		22.9%
$\Lambda(1520)\pi^+$	[q]	(2.4 ± 0.6) %		25.0%
$pK^-\pi^+$ nonresonant		(3.8 ± 0.4) %		10.5%
$p\overline{K}^0\pi^0$		(4.5 ± 0.6) %		13.3%
$p\overline{K}^0\eta$		(1.7 ± 0.4) %		23.5%
$p\overline{K}^0\pi^+\pi^-$		(3.5 ± 0.4) %		11.4%
$pK^-\pi^+\pi^0$		(4.6 ± 0.8) %		13.0%
$pK^*(892)^-\pi^+$	[q]	(1.5 ± 0.5) %		33.3%
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(5.0 ± 0.9) %		18.0%
$\Delta(1232)\overline{K}^*(892)$		seen		
$pK^-\pi^+\pi^+\pi^-$		$(1.5\pm1.0)\times10^{-3}$		66.7%
$pK^-\pi^+\pi^0\pi^0$		(1.1 ± 0.5) %		45.4%
Hadronic modes with a p: $S=0$ final states				
$p\pi^+\pi^-$		$(4.7\pm2.5)\times10^{-3}$		45.4%
$pf_0(980)$	[q]	$(3.8\pm2.5)\times10^{-3}$		53.2%
$p\pi^+\pi^+\pi^-\pi^-$		$(2.5\pm1.6)\times10^{-3}$		64.0%
pK^+K^-		$(1.1\pm0.4)\times10^{-3}$		36.4%
$p\phi$	[q]	$(1.12\pm0.23)\times10^{-3}$		
pK^+K^- non-ϕ		$(4.8\pm1.9)\times10^{-4}$		
Hadronic modes with a hyperon: $S=-1$ final states				
$\Lambda\pi^+$		(1.46 ± 0.13) %		8.9%
$\Lambda\pi^+\pi^0$		(5.0 ± 1.3) %		26.0%
$\Lambda\rho^+$		<6 %	CL=95%	
$\Lambda\pi^+\pi^+\pi^-$		(3.59 ± 0.28) %		7.8%
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+}\to\Lambda\pi^+$		(1.0 ± 0.5) %		20.0%
$\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-}\to\Lambda\pi^-$		$(7.5\pm1.4)\times10^{-3}$		18.7%

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				ΔB/B
$\Lambda\pi^+\rho^0$		(1.4 ± 0.6) %		42.8%
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+}\to\Lambda\pi^+$		$(5\pm4)\times10^{-3}$		80.0%
$\Lambda\pi^+\pi^+\pi^-$ nonresonant		<1.1 %	CL=90%	
$\Lambda\pi^+\pi^+\pi^-\pi^0$ total		(2.5 ± 0.9) %		36.0%
$\Lambda\pi^+\eta$	[q]	(2.4 ± 0.5) %		20.8%
$\Sigma(1385)^+\eta$	[q]	(1.16 ± 0.35) %		30.2%
$\Lambda\pi^+\omega$	[q]	(1.6 ± 0.6) %		37.5%
$\Lambda\pi^+\pi^+\pi^-\pi^0$, no η or ω		$<9\times10^{-3}$	CL=90%	
$\Lambda K^+\overline{K}^0$		$(6.4\pm1.3)\times10^{-3}$	S=1.6	20.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Lambda\overline{K}^0$		$(1.8\pm0.6)\times10^{-3}$		33.3%
$\Sigma^0\pi^+$		(1.43 ± 0.14) %		10.0%
$\Sigma^+\pi^0$		(1.37 ± 0.30) %		21.9%
$\Sigma^+\eta$		$(7.5\pm2.5)\times10^{-3}$		33.3%
$\Sigma^+\pi^+\pi^-$		(4.9 ± 0.5) %		10.2%
$\Sigma^+\rho^0$		<1.8 %	CL=95%	
$\Sigma^-\pi^+\pi^+$		(2.3 ± 0.4) %		17.4%
$\Sigma^0\pi^+\pi^0$		(2.5 ± 0.9) %		36.0%
$\Sigma^0\pi^+\pi^+\pi^-$		(1.13 ± 0.31) %		27.4%
$\Sigma^+\pi^+\pi^-\pi^0$		—		
$\Sigma^+\omega$	[q]	(3.7 ± 1.0) %		27.1%
$\Sigma^+K^+K^-$		$(3.8\pm0.6)\times10^{-3}$		15.8%
$\Sigma^+\phi$	[q]	$(4.3\pm0.7)\times10^{-3}$		16.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Sigma^+K^-$		$(1.11\pm0.29)\times10^{-3}$		26.2%
$\Sigma^+K^+K^-$ nonresonant		$<9\times10^{-4}$	CL=90%	
Ξ^0K^+		$(5.3\pm1.3)\times10^{-3}$		24.5%
$\Xi^-K^+\pi^+$		$(7.0\pm0.8)\times10^{-3}$	S=1.1	11.4%
$\Xi(1530)^0K^+$	[q]	$(3.5\pm1.0)\times10^{-3}$		28.6%
Hadronic modes with a hyperon: $S=0$ final states				
ΛK^+		$(6.9\pm1.4)\times10^{-4}$		20.3%
$\Lambda K^+\pi^+\pi^-$		$<6\times10^{-4}$	CL=90%	
Σ^0K^+		$(5.7\pm1.0)\times10^{-4}$		17.5%
$\Sigma^0K^+\pi^+\pi^-$		$<2.9\times10^{-4}$	CL=90%	
$\Sigma^+K^+\pi^-$		$(2.3\pm0.7)\times10^{-3}$		30.4%
$\Sigma^+K^*(892)^0$	[q]	$(3.8\pm1.2)\times10^{-3}$		31.6%
$\Sigma^-K^+\pi^+$		$<1.3\times10^{-3}$	CL=90%	
Doubly Cabibbo-suppressed modes				
$pK^+\pi^-$		$<3.1\times10^{-4}$	CL=90%	
Semileptonic modes				
$\Lambda\ell^+\nu_\ell$	[r]	(2.8 ± 0.4) %		
$\Lambda e^+\nu_e$		(2.9 ± 0.5) %		17.2%
$\Lambda\mu^+\nu_\mu$		(2.7 ± 0.6) %		22.2%

- ✓ *Total branching fraction ~60%.*
- ✓ *Lots of unknown decay channels*
- ✓ *Quite large uncertainties(>20%)*
- ✓ *Most BFs are measured relative to $\Lambda_c^+\to pK^-\pi^+$*

Λ_c^+ Measurements [PDG2020]

衰变分支比测量精度ΔB/B

衰变分支比测量精度ΔB/B

Λ_c^+ DECAY MODES		Fraction (Γ_i/		ΔB/B
Hadronic modes with a p or n: $S=-1$ final states				
pK_S^0		(1.59± 0.08) %	S=1.1	5.0%
$pK^-\pi^+$		(6.28± 0.32) %	S=1.4	5.1%
$p\overline{K}^*(892)^0$	[r]	(1.96± 0.27) %		13.8%
$\Delta(1232)^{++}K^-$		(1.08± 0.25) %		23.1%
$\Lambda(1520)\pi^+$	[r]	(2.2 ± 0.5) %		22.7%
$pK^-\pi^+$ nonresonant		(3.5 ± 0.4) %		11.5%
$pK_S^0\pi^0$		(1.97± 0.13) %	S=1.1	6.6%
$nK_S^0\pi^+$		(1.82± 0.25) %		13.7%
$p\overline{K}^0\eta$		(1.6 ± 0.4) %		25.0%
$pK_S^0\pi^+\pi^-$		(1.60± 0.12) %	S=1.1	7.5%
$pK^-\pi^+\pi^0$		(4.46± 0.30) %	S=1.5	6.8%
$pK^*(892)^-\pi^+$	[r]	(1.4 ± 0.5) %		35.7%
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(4.6 ± 0.8) %		17.4%
$\Delta(1232)\overline{K}^*(892)$		seen		
$pK^-2\pi^+\pi^-$		(1.4 ± 0.9) × 10^{-3}		64.3%
$pK^-\pi^+2\pi^0$		(1.0 ± 0.5) %		50.0%
Hadronic modes with a p: $S=0$ final states				
$p\pi^0$		< 2.7 × 10^{-4}	CL=90%	
$p\eta$		(1.24± 0.30) × 10^{-3}		24.2%
$p\omega(782)^0$		(9 ± 4) × 10^{-4}		44.4%
$p\pi^+\pi^-$		(4.61± 0.28) × 10^{-3}		6.1%
$pf_0(980)$	[r]	(3.5 ± 2.3) × 10^{-3}		65.7%
$p2\pi^+2\pi^-$		(2.3 ± 1.4) × 10^{-3}		60.9%
pK^+K^-		(1.06± 0.06) × 10^{-3}		5.7%
$p\phi$	[r]	(1.06± 0.14) × 10^{-3}		13.2%
pK^+K^- non-ϕ		(5.3 ± 1.2) × 10^{-4}		22.6%
$p\phi\pi^0$		(10 ± 4) × 10^{-5}		40.0%
$pK^+K^-\pi^0$ nonresonant		< 6.3 × 10^{-5}	CL=90%	
Hadronic modes with a hyperon: $S=-1$ final states				
$\Lambda\pi^+$		(1.30± 0.07) %	S=1.1	5.4%
$\Lambda\pi^+\pi^0$		(7.1 ± 0.4) %	S=1.1	5.6%
$\Lambda\rho^+$		< 6 %	CL=95%	
$\Lambda\pi^-2\pi^+$		(3.64± 0.29) %	S=1.4	8.0%
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+}\to\Lambda\pi^+$		(1.0 ± 0.5) %		50.0%
$\Sigma(1385)^-2\pi^+$, $\Sigma^{*-}\to\Lambda\pi^-$		(7.6 ± 1.4) × 10^{-3}		18.4%
$\Lambda\pi^+\rho^0$		(1.5 ± 0.6) %		40.0%
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+}\to\Lambda\pi^+$		(5 ± 4) × 10^{-3}		80.0%
$\Lambda\pi^-2\pi^+$ nonresonant		< 1.1 %	CL=90%	

				ΔB/B
$\Lambda\pi^-\pi^02\pi^+$ total		(2.3 ± 0.8) %		34.8%
$\Lambda\pi^+\eta$	[r]	(1.84± 0.26) %		14.1%
$\Sigma(1385)^+\eta$	[r]	(9.1 ± 2.0) × 10^{-3}		21.9%
$\Lambda\pi^+\omega$	[r]	(1.5 ± 0.5) %		33.3%
$\Lambda\pi^-\pi^02\pi^+$, no η or ω		< 8 × 10^{-3}	CL=90%	
$\Lambda K^+\overline{K}^0$		(5.7 ± 1.1) × 10^{-3}	S=1.9	19.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Lambda\overline{K}^0$		(1.6 ± 0.5) × 10^{-3}		31.2%
$\Sigma^0\pi^+$		(1.29± 0.07) %	S=1.1	5.4%
$\Sigma^+\pi^0$		(1.25± 0.10) %		8.0%
$\Sigma^+\eta$		(4.4 ± 2.0) × 10^{-3}		45.4%
$\Sigma^+\eta'$		(1.5 ± 0.6) %		40.0%
$\Sigma^+\pi^+\pi^-$		(4.50± 0.25) %	S=1.3	5.6%
$\Sigma^+\rho^0$		< 1.7 %	CL=95%	
$\Sigma^-2\pi^+$		(1.87± 0.18) %		9.6%
$\Sigma^0\pi^+\pi^0$		(3.5 ± 0.4) %		11.4%
$\Sigma^+\pi^0\pi^0$		(1.55± 0.15) %		9.7%
$\Sigma^0\pi^-2\pi^+$		(1.11± 0.30) %		27.0%
$\Sigma^+\pi^+\pi^-\pi^0$		—		
$\Sigma^+\omega$	[r]	(1.70± 0.21) %		12.4%
$\Sigma^-\pi^02\pi^+$		(2.1 ± 0.4) %		19.0%
$\Sigma^+K^+K^-$		(3.5 ± 0.4) × 10^{-3}	S=1.1	11.4%
$\Sigma^+\phi$	[r]	(3.9 ± 0.6) × 10^{-3}	S=1.1	15.4%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Sigma^+K^-$		(1.02± 0.25) × 10^{-3}		24.5%
$\Sigma^+K^+K^-$ nonresonant		< 8 × 10^{-4}	CL=90%	
Ξ^0K^+		(5.5 ± 0.7) × 10^{-3}		12.7%
$\Xi^-K^+\pi^+$		(6.2 ± 0.6) × 10^{-3}	S=1.1	9.7%
$\Xi(1530)^0K^+$		(4.3 ± 0.9) × 10^{-3}	S=1.1	20.9%
Hadronic modes with a hyperon: $S=0$ final states				
ΛK^+		(6.1 ± 1.2) × 10^{-4}		19.7%
$\Lambda K^+\pi^+\pi^-$		< 5 × 10^{-4}	CL=90%	
Σ^0K^+		(5.2 ± 0.8) × 10^{-4}		15.4%
$\Sigma^0K^+\pi^+\pi^-$		< 2.6 × 10^{-4}	CL=90%	
$\Sigma^+K^+\pi^-$		(2.1 ± 0.6) × 10^{-3}		28.6%
$\Sigma^+K^*(892)^0$	[r]	(3.5 ± 1.0) × 10^{-3}		28.6%
$\Sigma^-K^+\pi^+$		< 1.2 × 10^{-3}	CL=90%	
Doubly Cabibbo-suppressed modes				
$pK^+\pi^-$		(1.11± 0.18) × 10^{-4}		16.2%
Semileptonic modes				
$\Lambda e^+\nu_e$		(3.6 ± 0.4) %		11.1%
$\Lambda\mu^+\nu_\mu$		(3.5 ± 0.5) %		14.3%

Λ_c^+ Measurements [PDG2022]

衰变分支比测量精度ΔB/B

Λ_c^+ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor / Confidence level	ΔB/B
Hadronic modes with a p or n: $S=-1$ final states				
pK_S^0		(1.59 ± 0.08) %	S=1.1	5.0%
$pK^-\pi^+$		(6.28 ± 0.32) %	S=1.4	5.1%
$p\overline{K}^*(892)^0$	[r]	(1.96 ± 0.27) %		13.8%
$\Delta(1232)^{++}K^-$		(1.08 ± 0.25) %		23.1%
$\Lambda(1520)\pi^+$	[r]	(2.2 ± 0.5) %		22.7%
$pK^-\pi^+$ nonresonant		(3.5 ± 0.4) %		11.5%
$pK_S^0\pi^0$		(1.97 ± 0.13) %	S=1.1	6.6%
$nK_S^0\pi^+$		(1.82 ± 0.25) %		13.7%
$p\overline{K}^0\eta$		$(8.3\pm1.8)\times10^{-3}$		21.7%
$pK_S^0\pi^+\pi^-$		(1.60 ± 0.12) %	S=1.1	7.5%
$pK^-\pi^+\pi^0$		(4.46 ± 0.30) %	S=1.5	6.8%
$pK^*(892)^-\pi^+$	[r]	(1.4 ± 0.5) %		35.7%
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(4.6 ± 0.8) %		17.4%
$\Delta(1232)\overline{K}^*(892)$		seen		
$pK^-2\pi^+\pi^-$		$(1.4\pm0.9)\times10^{-3}$		64.3%
$pK^-\pi^+2\pi^0$		(1.0 ± 0.5) %		50.0%
Hadronic modes with a p: $S=0$ final states				
$p\pi^0$		$<8\times10^{-5}$	CL=90%	
$p\eta$		$(1.42\pm0.12)\times10^{-3}$		8.4%
$p\omega(782)^0$		$(8.3\pm1.1)\times10^{-4}$		13.2%
$p\pi^+\pi^-$		$(4.61\pm0.28)\times10^{-3}$		6.0%
$pf_0(980)$	[r]	$(3.5\pm2.3)\times10^{-3}$		65.7%
$p2\pi^+2\pi^-$		$(2.3\pm1.4)\times10^{-3}$		60.8%
pK^+K^-		$(1.06\pm0.06)\times10^{-3}$		5.6%
$p\phi$	[r]	$(1.06\pm0.14)\times10^{-3}$		13.2%
pK^+K^- non-ϕ		$(5.3\pm1.2)\times10^{-4}$		22.6%
$p\phi\pi^0$		$(10\pm4)\times10^{-5}$		40.0%
$pK^+K^-\pi^0$ nonresonant		$<6.3\times10^{-5}$	CL=90%	
Inclusive modes				
e^+ anything		(3.95 ± 0.35) %		8.9%
p anything		(50 ± 16) %		32.0%
n anything		(50 ± 16) %		32.0%
Λ anything		$(38.2\,^{+2.9}_{-2.4})$ %		~7.0%
K_S^0 anything		(9.9 ± 0.7) %		7.1%
3prongs		(24 ± 8) %		33.3%

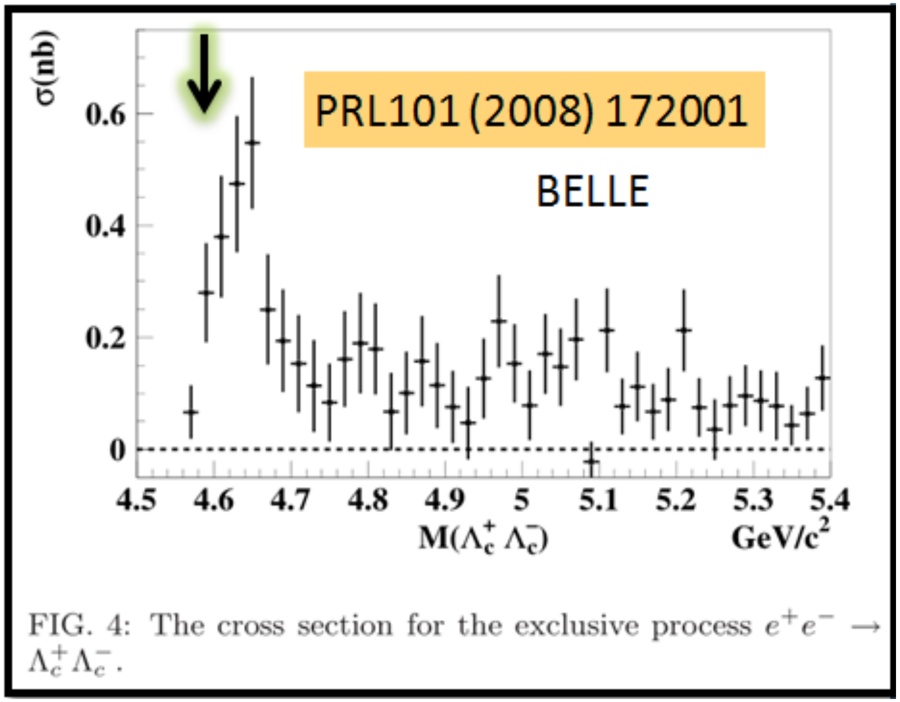
Mode		Fraction (Γ_i/Γ)	Scale factor / Confidence level	ΔB/B
Hadronic modes with a hyperon: $S=-1$ final states				
$\Lambda\pi^+$		(1.30 ± 0.07) %	S=1.1	5.4%
$\Lambda(1670)\pi^+$, $\Lambda(1670)\to\eta\Lambda$		$(3.5\pm0.5)\times10^{-3}$		14.3%
$\Lambda\pi^+\pi^0$		(7.1 ± 0.4) %	S=1.1	5.6%
$\Lambda\rho^+$		<6 %	CL=95%	
$\Lambda\pi^-2\pi^+$		(3.64 ± 0.29) %	S=1.4	8.0%
$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+}\to\Lambda\pi^+$		(1.0 ± 0.5) %		50.0%
$\Sigma(1385)^-2\pi^+$, $\Sigma^{*-}\to\Lambda\pi^-$		$(7.6\pm1.4)\times10^{-3}$		18.4%
$\Lambda\pi^+\rho^0$		(1.5 ± 0.6) %		40.0%
$\Sigma(1385)^+\rho^0$, $\Sigma^{*+}\to\Lambda\pi^+$		$(5\pm4)\times10^{-3}$		80.0%
$\Lambda\pi^-2\pi^+$ nonresonant		<1.1 %	CL=90%	
$\Lambda\pi^-\pi^0 2\pi^+$ total		(2.3 ± 0.8) %		34.8%
$\Lambda\pi^+\eta$	[r]	(1.84 ± 0.26) %		14.1%
$\Sigma(1385)^+\eta$	[r]	$(9.1\pm2.0)\times10^{-3}$		21.9%
$\Lambda\pi^+\omega$	[r]	(1.5 ± 0.5) %		33.3%
$\Lambda\pi^-\pi^0 2\pi^+$, no η or ω		$<8\times10^{-3}$	CL=90%	
$\Lambda K^+\overline{K}^0$		$(5.7\pm1.1)\times10^{-3}$	S=1.9	19.3%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Lambda\overline{K}^0$		$(1.6\pm0.5)\times10^{-3}$		31.2%
$\Sigma^0\pi^+$		(1.29 ± 0.07) %	S=1.1	5.4%
$\Sigma^0\pi^+\eta$		$(7.5\pm0.8)\times10^{-3}$		10.7%
$\Sigma^+\pi^0$		(1.25 ± 0.10) %		8.0%
$\Sigma^+\eta$		$(4.4\pm2.0)\times10^{-3}$		45.4%
$\Sigma^+\eta'$		(1.5 ± 0.6) %		40.0%
$\Sigma^+\pi^+\pi^-$		(4.50 ± 0.25) %	S=1.3	5.6%
$\Sigma^+\rho^0$		<1.7 %	CL=95%	
$\Sigma^-2\pi^+$		(1.87 ± 0.18) %		9.6%
$\Sigma^0\pi^+\pi^0$		(3.5 ± 0.4) %		11.4%
$\Sigma^+\pi^0\pi^0$		(1.55 ± 0.15) %		9.7%
$\Sigma^0\pi^-2\pi^+$		(1.11 ± 0.30) %		27.0%
$\Sigma^+\pi^+\pi^-\pi^0$		—		
$\Sigma^+\omega$	[r]	(1.70 ± 0.21) %		12.4%
$\Sigma^-\pi^0 2\pi^+$		(2.1 ± 0.4) %		19.0%
$\Sigma^+K^+K^-$		$(3.5\pm0.4)\times10^{-3}$	S=1.1	11.4%
$\Sigma^+\phi$	[r]	$(3.9\pm0.6)\times10^{-3}$	S=1.1	15.4%
$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Sigma^+K^-$		$(1.02\pm0.25)\times10^{-3}$		24.5%
$\Sigma^+K^+K^-$ nonresonant		$<8\times10^{-4}$	CL=90%	
Ξ^0K^+		$(5.5\pm0.7)\times10^{-3}$		12.7%
$\Xi^-K^+\pi^+$		$(6.2\pm0.6)\times10^{-3}$	S=1.1	9.7%
$\Xi(1530)^0K^+$		$(4.3\pm0.9)\times10^{-3}$	S=1.1	20.9%
Hadronic modes with a hyperon: $S=0$ final states				
ΛK^+		$(6.1\pm1.2)\times10^{-4}$		19.7%
$\Lambda K^+\pi^+\pi^-$		$<5\times10^{-4}$	CL=90%	
Σ^0K^+		$(5.2\pm0.8)\times10^{-4}$		15.4%
$\Sigma^0K^+\pi^+\pi^-$		$<2.6\times10^{-4}$	CL=90%	
$\Sigma^+K^+\pi^-$		$(2.1\pm0.6)\times10^{-3}$		28.6%
$\Sigma^+K^*(892)^0$	[r]	$(3.5\pm1.0)\times10^{-3}$		28.6%
$\Sigma^-K^+\pi^+$		$<1.2\times10^{-3}$	CL=90%	
Doubly Cabibbo-suppressed modes				
$pK^+\pi^-$		$(1.11\pm0.18)\times10^{-4}$		16.2%
Semileptonic modes				
$\Lambda e^+\nu_e$		(3.6 ± 0.4) %		11.1%
$\Lambda\mu^+\nu_\mu$		(3.5 ± 0.5) %		14.3%

Measurements for Λ_c^+ decays are greatly improved, with great efforts from BESIII, LHCb and Belle.

Λ_c Data samples at BESIII

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

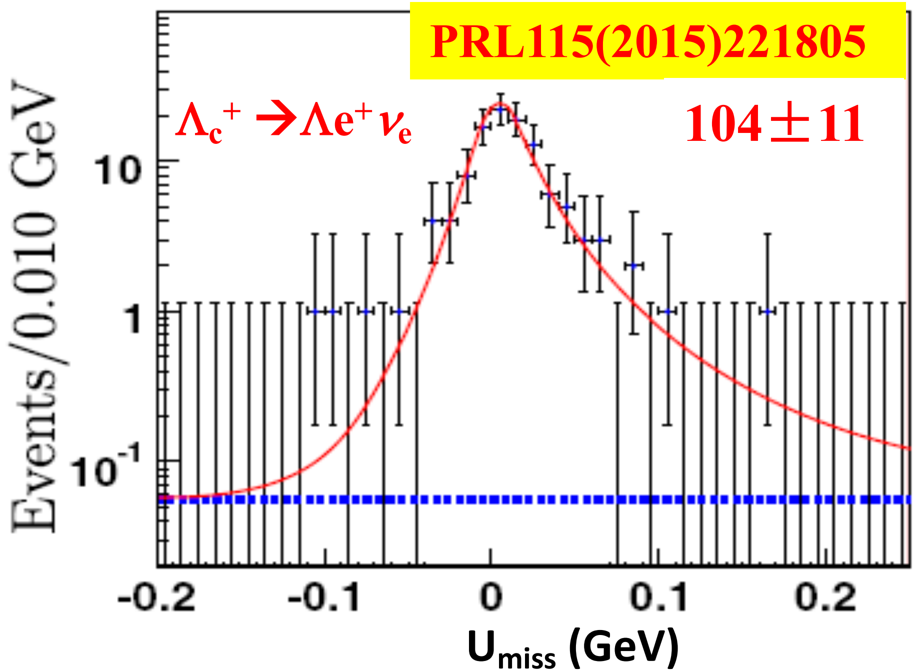
Energy (GeV)	Luminosity (pb^{-1})
4.575	~48
4.580	~8.5
4.590	~8.1
4.599	~567

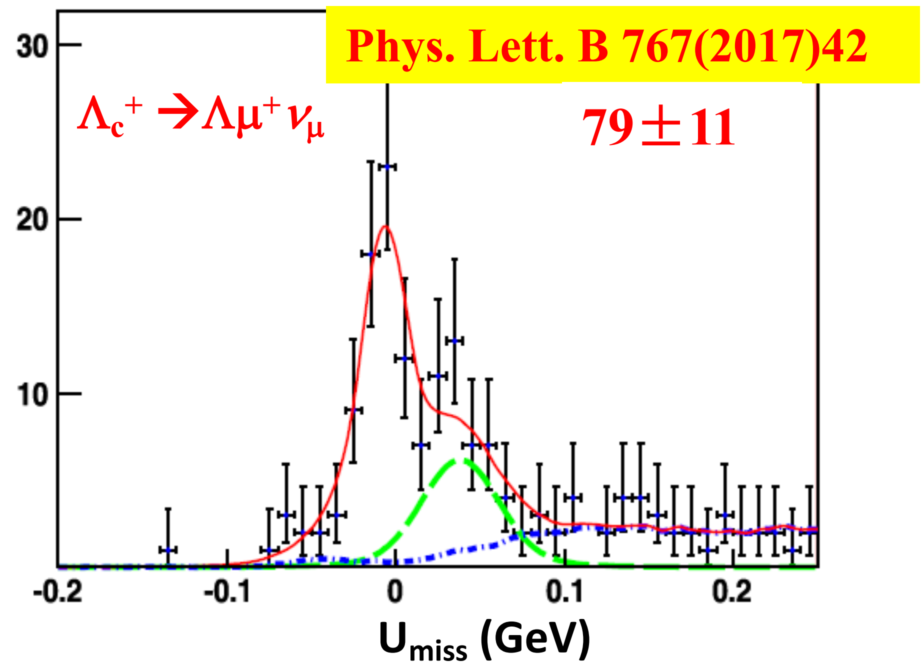


With 567/pb data collected at E_{cm}=4.599 GeV, lots of the works are performed to study the decay property of Λ_c at BESIII.

$\Lambda_c^+ \rightarrow \Lambda l^+ \nu_l$ decays

- Theoretical calculations on the BF ranges from 1.4% to 9.2%
- BESIII performed the first absolute BF measurements.
- The BFs provide complementary information on determining $|V_{cs}|$.





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

$B[\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu_\mu] = (3.49 \pm 0.46 \pm 0.26)\%$

$\Gamma[\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu_\mu]/\Gamma[\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e] = 0.96 \pm 0.16 \pm 0.04$

Provides important input for calibrating the LQCD 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)
BESIII [First absolute measurement]	3.63 ± 0.43	PRL 115, 221805 (2015)]

PRL **118,** 082001 (2017) PHYSICAL REVIEW LETTERS week ending 24 FEBRUARY 2017

$\Lambda_c \to \Lambda l^+ \nu_l$ Form Factors and Decay Rates from Lattice QCD with Physical Quark Masses

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(Received 1 December 2016; published 21 February 2017)

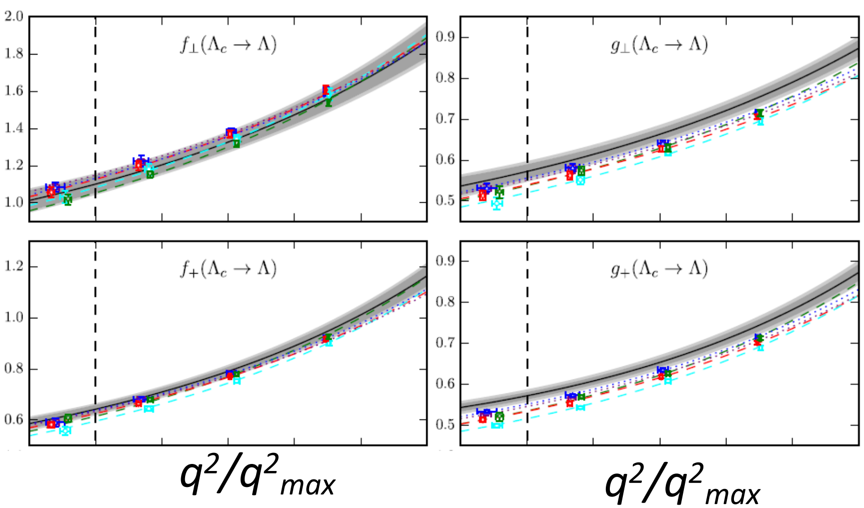
- Expectations from Lattice QCD on BFs

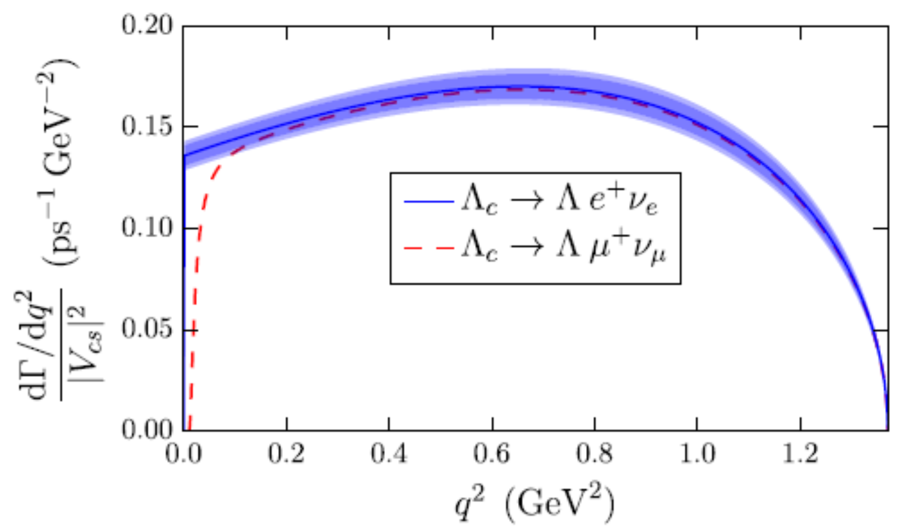
$$\mathcal{B}(\Lambda_c \to \Lambda \ell^+ \nu_\ell) = \begin{cases} 0.0380(19)_{\rm LQCD}(11)_{\tau_{\Lambda_c}}, & \ell = e, \\ 0.0369(19)_{\rm LQCD}(11)_{\tau_{\Lambda_c}}, & \ell = \mu, \end{cases}$$

BESIII results:

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

- Expectations from Lattice QCD on form factors and differential decay widths



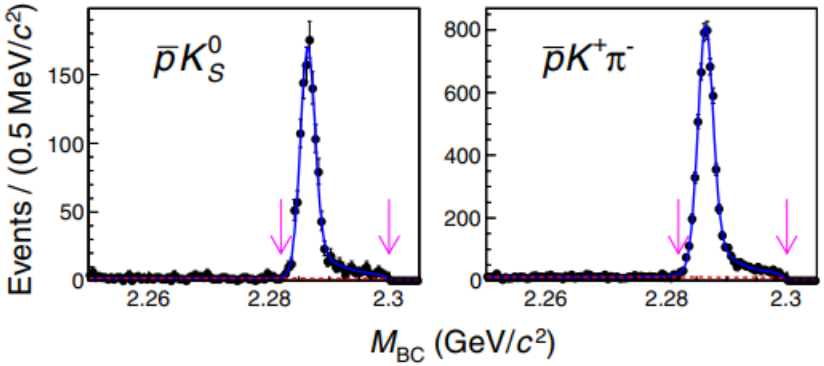


- BESIII can provide the first direct test on LQCD predictions.

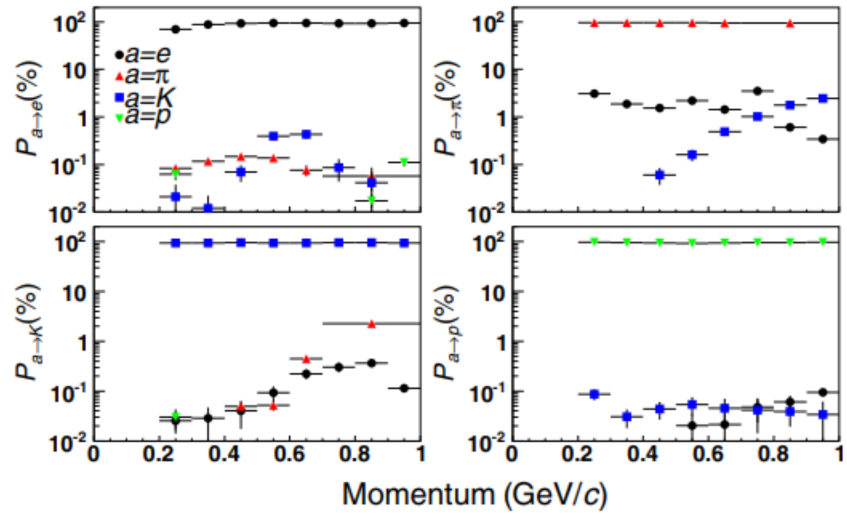
Inclusive SL decay $\Lambda_c^+ \rightarrow e^+X$

PRL121(2018)251801

- ✓ Two tags are used in analysis



- ✓ PID efficiencies obtained from data



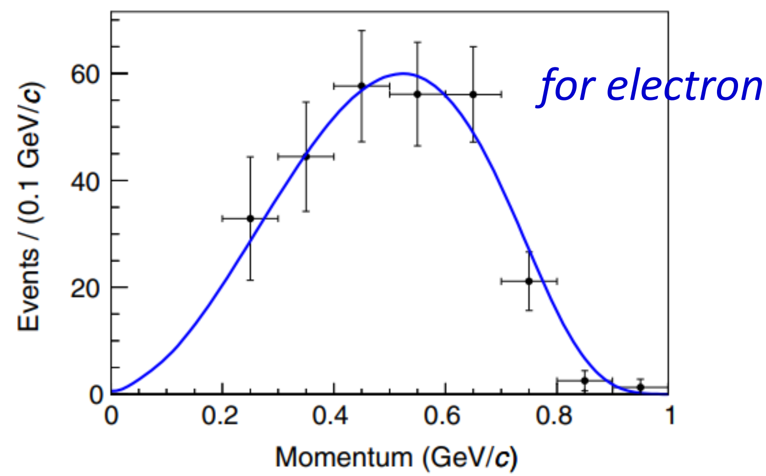
- ✓ Unfolding method to obtain signals

$$\begin{pmatrix} N_e^{obs} \\ N_\pi^{obs} \\ N_K^{obs} \\ N_p^{obs} \end{pmatrix} = \begin{pmatrix} P_{e\to e} & P_{\pi\to e} & P_{K\to e} & P_{p\to e} \\ P_{e\to \pi} & P_{\pi\to \pi} & P_{K\to \pi} & P_{p\to \pi} \\ P_{e\to K} & P_{\pi\to K} & P_{K\to K} & P_{p\to K} \\ P_{e\to p} & P_{\pi\to p} & P_{K\to p} & P_{p\to p} \end{pmatrix} \begin{pmatrix} N_e^{true} \\ N_\pi^{true} \\ N_K^{true} \\ N_p^{true} \end{pmatrix}$$

- ✓ The extracted BFs for $\Lambda_c^+ \rightarrow eX$

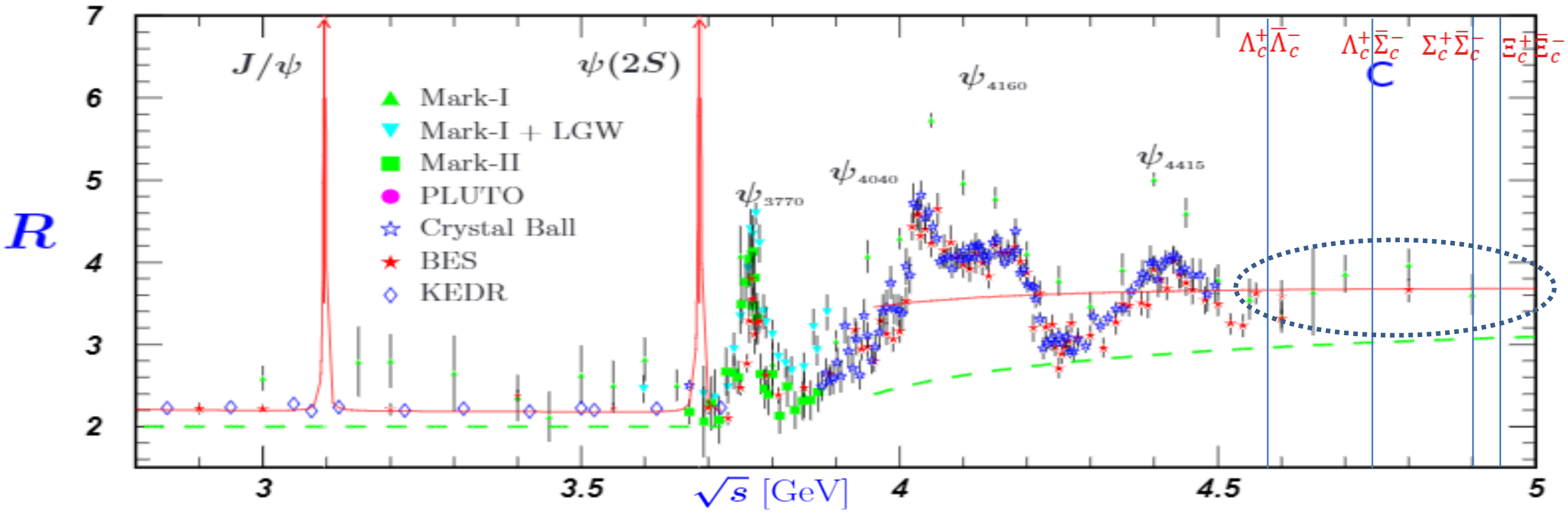
$B[\Lambda_c^+ \rightarrow e+X]=(3.95\pm0.34\pm0.09)\%$

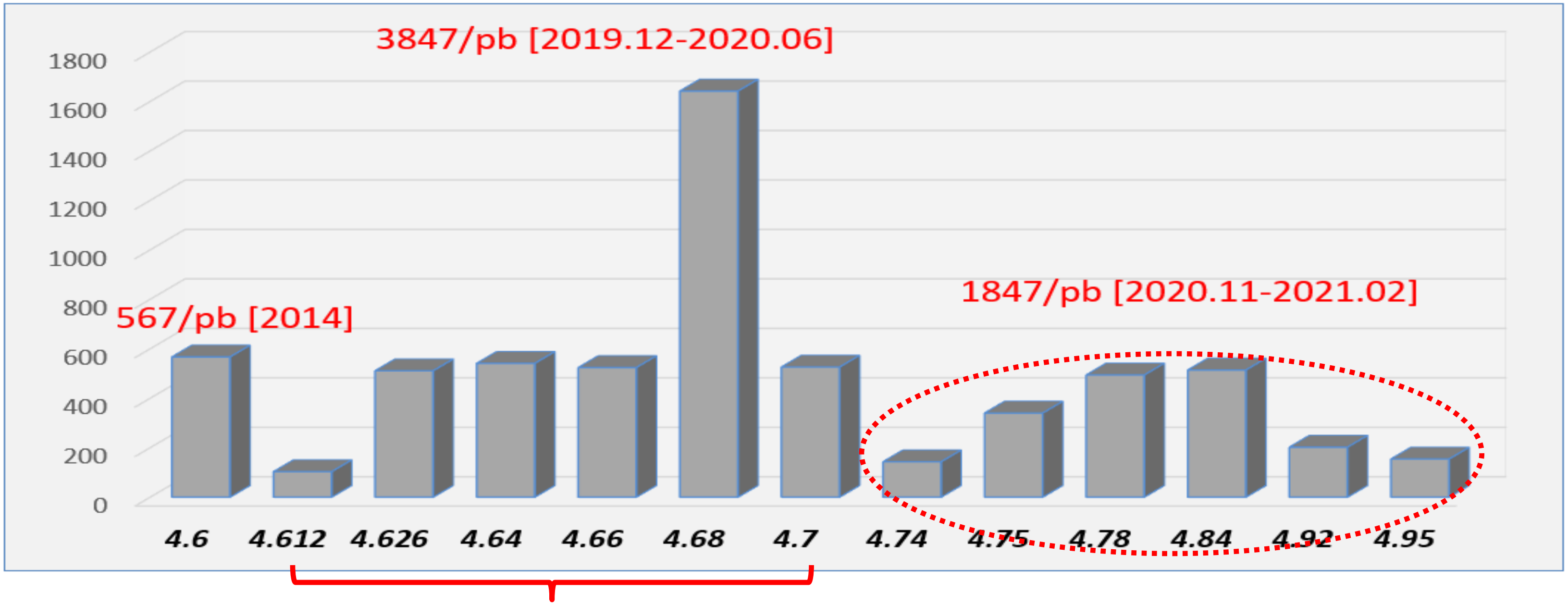
Result	$\Lambda_c^+ \to Xe^+\nu_e$	$[\Gamma(\Lambda_c^+ \to Xe^+\nu_e)/\bar{\Gamma}(D \to Xe^+\nu_e)]$
BESIII	3.95 ± 0.35	1.26 ± 0.12
MARK II [11]	4.5 ± 1.7	1.44 ± 0.54
Effective-quark method [8,9]		1.67
Heavy-quark expansion [10]		1.2



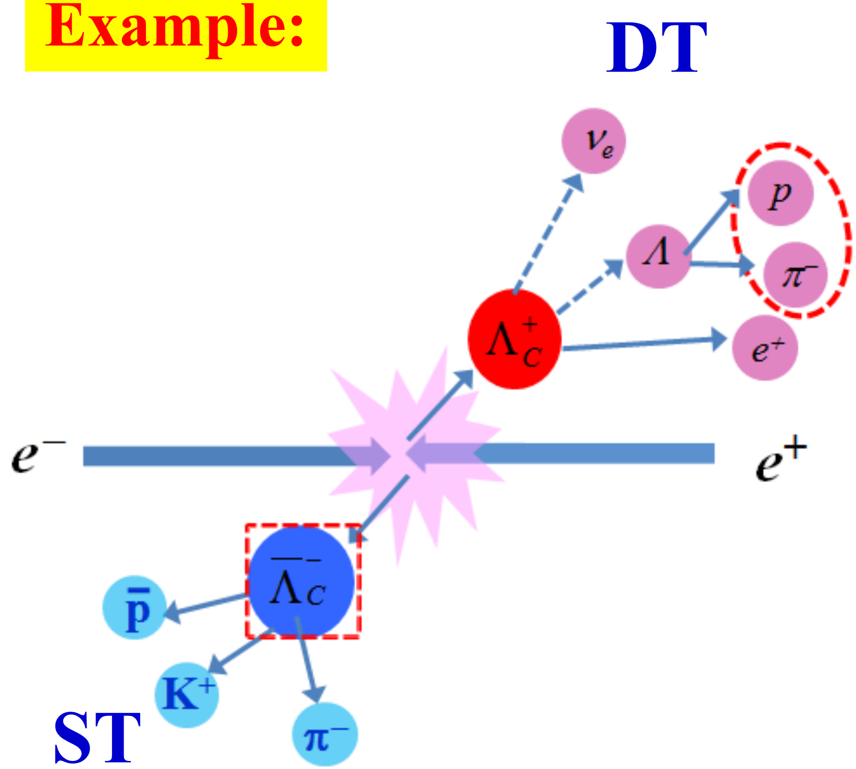
$$\frac{B(\Lambda_c^+ \to \Lambda e^+\nu_e)}{B(\Lambda_c^+ \to e^+X)} = (91.9 \pm 12.5 \pm 5.4)\%$$

Data sets for charm baryon studies at BESIII





DT 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.

Reconstruction of Λ_c ST baryons

- Fourteen ST modes:

PDG2022

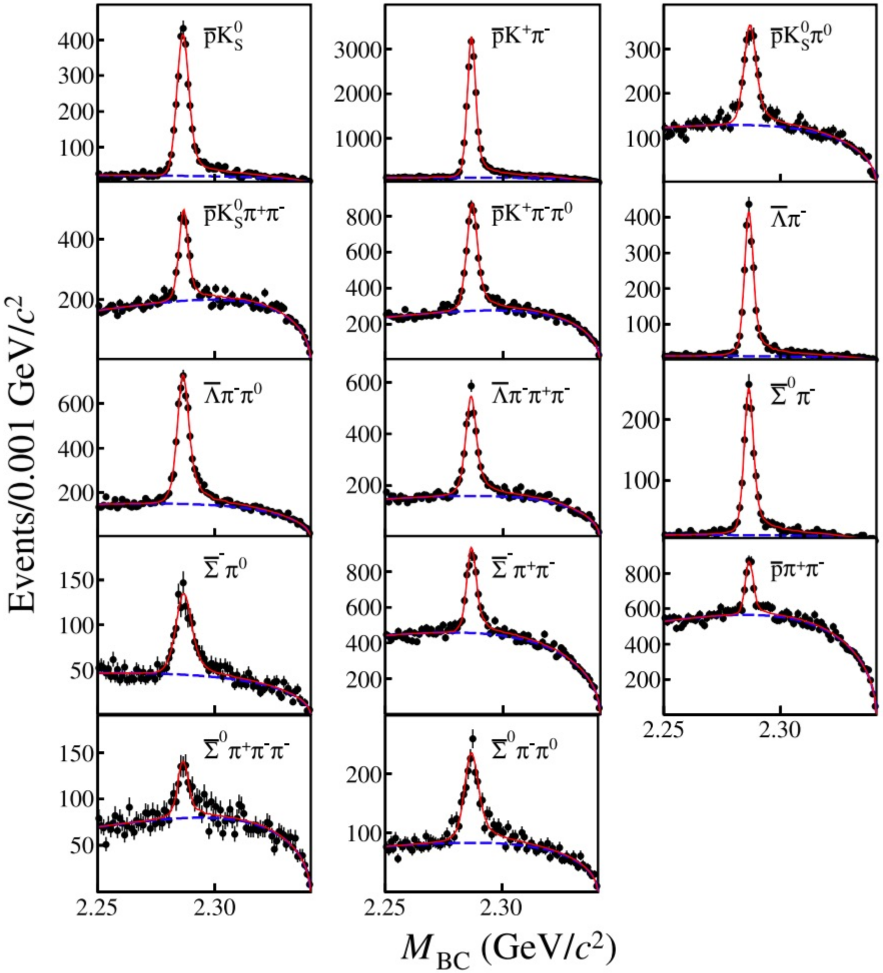
$\bar{\Lambda}_c^- \to$	Branching fraction
$\bar{p}\bar{K}^0$	$(3.18 \pm 0.16)\%$
$\bar{p}K^+\pi^-$	$(6.28 \pm 0.32)\%$
$\bar{p}\bar{K}^0\pi^0$	$(3.94 \pm 0.26)\%$
$\bar{p}\bar{K}^0\pi^+\pi^-$	$(3.20 \pm 0.24)\%$
$\bar{p}K^+\pi^-\pi^0$	$(4.46 \pm 0.30)\%$
$\bar{\Lambda}\pi^-$	$(1.30 \pm 0.07)\%$
$\bar{\Lambda}\pi^-\pi^0$	$(7.10 \pm 0.40)\%$
$\bar{\Lambda}\pi^-\pi^+\pi^-$	$(3.64 \pm 0.29)\%$
$\bar{\Sigma}^0\pi^-$	$(1.29 \pm 0.07)\%$
$\bar{\Sigma}^-\pi^0$	$(1.25 \pm 0.10)\%$
$\bar{\Sigma}^-\pi^+\pi^-$	$(4.50 \pm 0.25)\%$
$\bar{p}^-\pi^+\pi^-$	$(0.46 \pm 0.03)\%$
$\bar{\Sigma}^0\pi^+\pi^-\pi^-$	$(1.11 \pm 0.30)\%$
$\bar{\Sigma}^0\pi^-\pi^0$	$(3.50 \pm 0.40)\%$

~45%

Currently, the total measured BFs for Λ_c decays is roughly 70%.

Reconstruction of Λ_c ST baryons

- The M_{BC} distritbutions at $\sqrt{s} = 4.68$ GeV.



Mode	ΔE (GeV)	N_{ST}
$\bar{p}\bar{K}^0$	$[-0.031, 0.033]$	7688 ± 98
$\bar{p}K^+\pi^-$	$[-0.030, 0.039]$	45842 ± 235
$\bar{p}\bar{K}^0\pi^0$	$[-0.049, 0.052]$	4448 ± 109
$\bar{p}\bar{K}^0\pi^+\pi^-$	$[-0.048, 0.049]$	4962 ± 110
$\bar{p}K^+\pi^-\pi^0$	$[-0.043, 0.051]$	10670 ± 161
$\bar{\Lambda}\pi^-$	$[-0.031, 0.034]$	6089 ± 82
$\bar{\Lambda}\pi^-\pi^0$	$[-0.044, 0.057]$	11933 ± 143
$\bar{\Lambda}\pi^-\pi^+\pi^-$	$[-0.043, 0.045]$	7163 ± 122
$\bar{\Sigma}^0\pi^-$	$[-0.032, 0.040]$	3883 ± 69
$\bar{\Sigma}^-\pi^0$	$[-0.050, 0.060]$	2289 ± 70
$\bar{\Sigma}^-\pi^+\pi^-$	$[-0.043, 0.052]$	8206 ± 161
$\bar{p}^-\pi^+\pi^-$	$[-0.040, 0.040]$	4199 ± 139
$\bar{\Sigma}^0\pi^+\pi^-\pi^-$	$[-0.030, 0.030]$	1290 ± 64
$\bar{\Sigma}^0\pi^-\pi^0$	$[-0.030, 0.032]$	3606 ± 90

Totally, 122 268±474 ST events are reconstructed with 14 ST modes.

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

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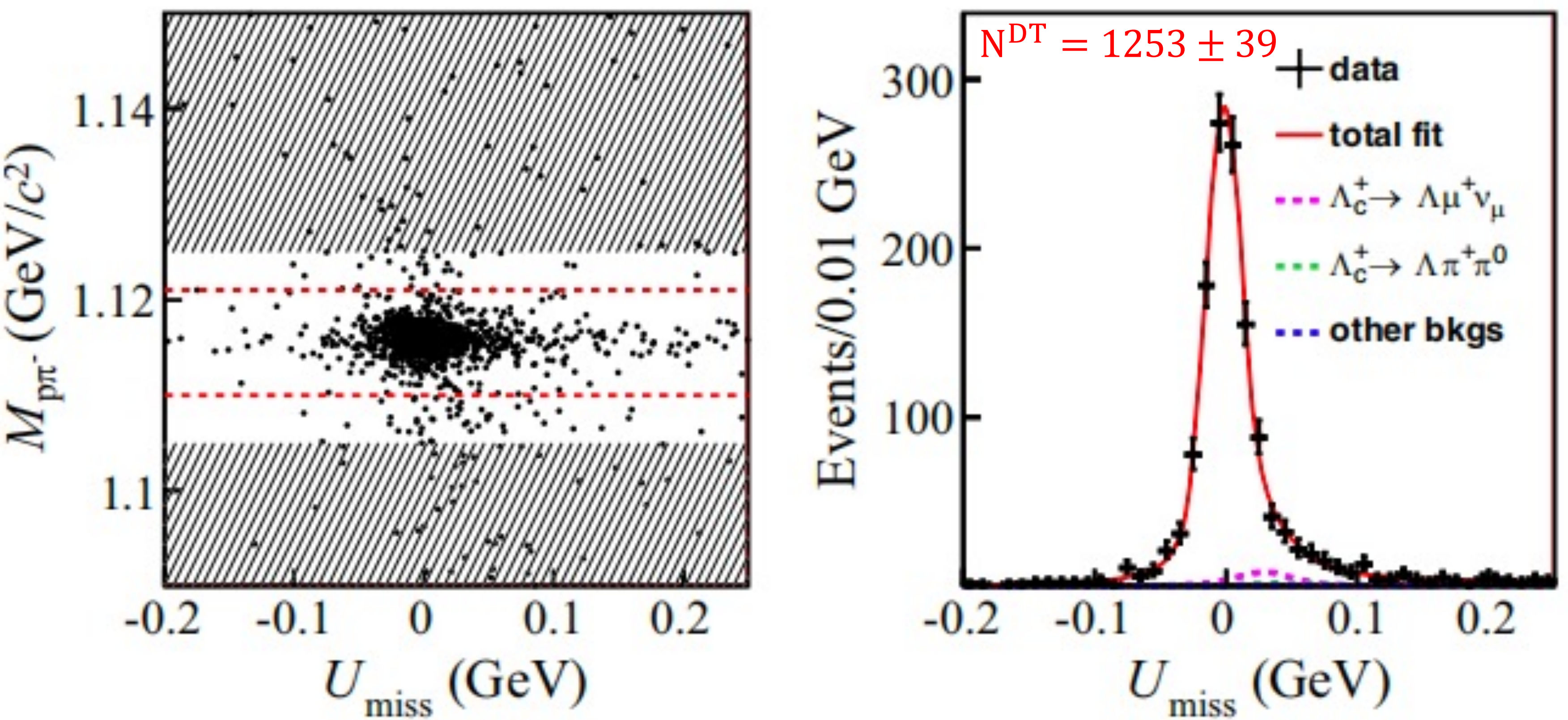


BESIII result: $B[\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e] = (3.56 \pm 0.11 \pm 0.07)\%$

The precision of the BF is improved by threefold.

The measured BF is important to test various theoretical calculations.

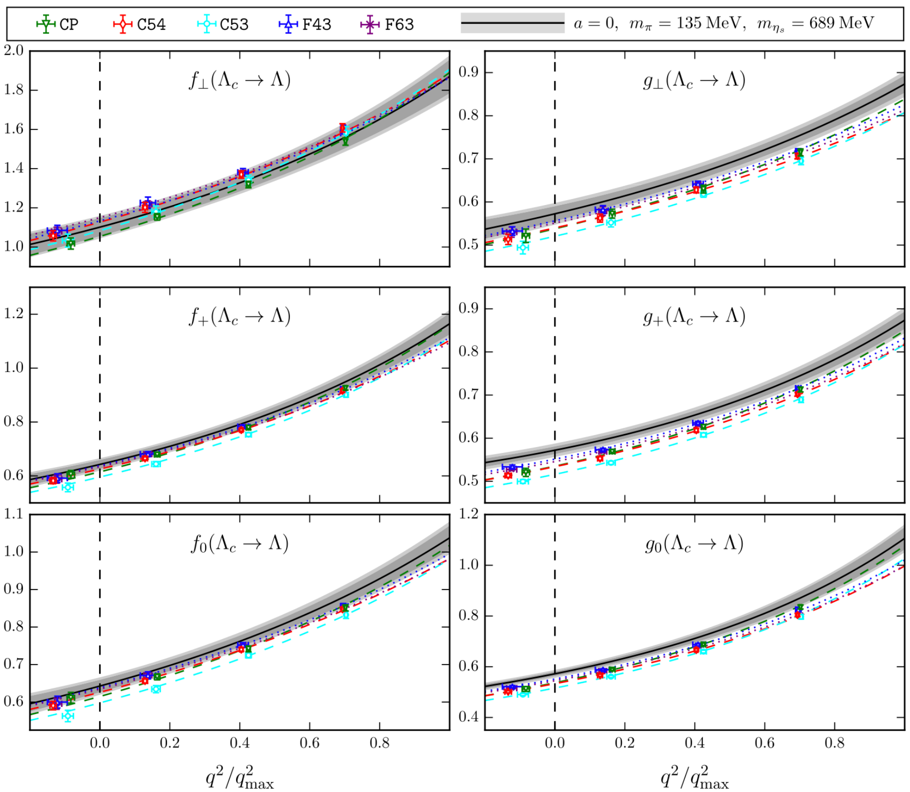
	$\mathcal{B}(\Lambda_c^+ \to \Lambda e^+ \nu_e)$ (%)	
Constituent quark model (HONR) [9]	4.25	×
Light-front approach [10]	1.63	×
Covariant quark model [11]	2.78	×
Relativistic quark model [12]	3.25	×
Non-relativistic quark model [13]	3.84	
Light-cone sum rule [14]	3.0 ± 0.3	
Lattice QCD [15]	3.80 ± 0.22	
$SU(3)$ [16]	3.6 ± 0.4	
Light-front constituent quark model [17]	3.36 ± 0.87	
MIT bag model [17]	3.48	
Light-front quark model [18]	4.04 ± 0.75	
This Letter	$3.56 \pm 0.11 \pm 0.07$	

PRL118(2017)082001

$\Lambda_c \to \Lambda l^+ \nu_l$ Form Factors and Decay Rates from Lattice QCD with Physical Quark Masses

LQCD prediction：

$$f(q^2) = \frac{1}{1 - q^2/(m_{\rm pole}^f)^2} \sum_{n=0}^{n_{\rm max}} a_n^f [z(q^2)]^n$$



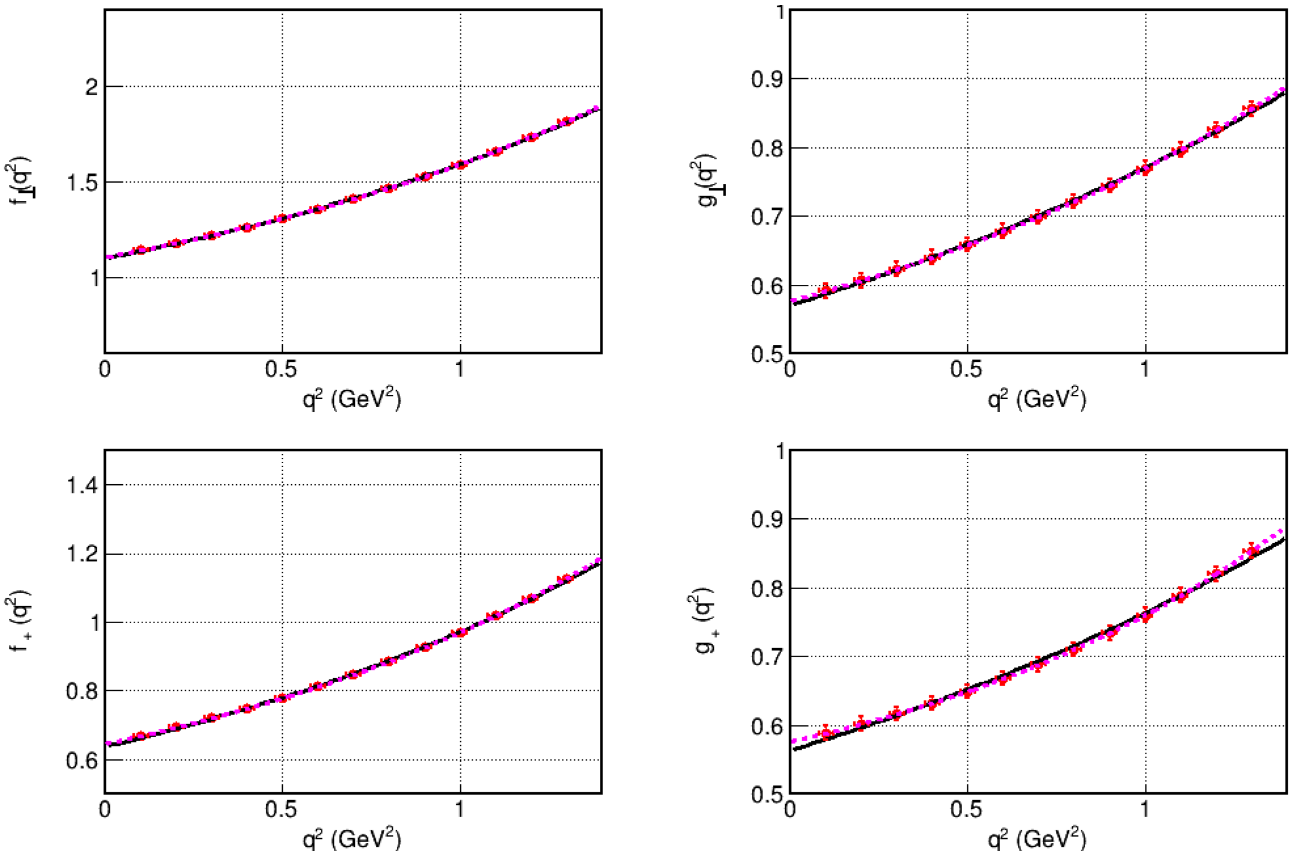
$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 |V_{cs}|^2}{192\pi^3 M_{\Lambda_c}^2} \times P \times q^2(1 - m_\ell^2/q^2)^2 \times [|H_{\frac{1}{2}1}|^2 + |H_{-\frac{1}{2}-1}|^2 + |H_{\frac{1}{2}0}|^2 + |H_{-\frac{1}{2}0}|^2$$
$$+ \frac{m_\ell^2}{2q^2}(3|H_{\frac{1}{2}t}|^2 + 3|H_{-\frac{1}{2}t}|^2 + |H_{\frac{1}{2}1}|^2 + |H_{-\frac{1}{2}-1}|^2 + |H_{\frac{1}{2}0}|^2 + |H_{-\frac{1}{2}0}|^2)]$$

	Nominal fit	Higher-order fit
$a_0^{f_\perp}$	1.30 ± 0.06	1.28 ± 0.07
$a_1^{f_\perp}$	-3.27 ± 1.18	-2.85 ± 1.34
$a_2^{f_\perp}$	7.16 ± 11.6	7.14 ± 12.2
$a_3^{f_\perp}$		-1.08 ± 30.0
$a_0^{f_+}$	0.81 ± 0.03	0.79 ± 0.04
$a_1^{f_+}$	-2.89 ± 0.52	-2.38 ± 0.61
$a_2^{f_+}$	7.82 ± 4.53	6.64 ± 6.07
$a_3^{f_+}$		-1.08 ± 29.8
$a_0^{f_0}$	0.77 ± 0.02	0.76 ± 0.03
$a_1^{f_0}$	-2.24 ± 0.51	-1.77 ± 0.58
$a_2^{f_0}$	5.38 ± 4.80	4.93 ± 6.28
$a_3^{f_0}$		-0.26 ± 29.8
$a_0^{g_\perp, g_+}$	0.68 ± 0.02	0.67 ± 0.02
$a_1^{g_\perp}$	-1.91 ± 0.35	-1.73 ± 0.54
$a_2^{g_\perp}$	6.24 ± 4.89	5.97 ± 6.64
$a_3^{g_\perp}$		-1.68 ± 29.8
$a_1^{g_+}$	-2.44 ± 0.25	-2.22 ± 0.35
$a_2^{g_+}$	13.7 ± 2.15	12.1 ± 4.43
$a_3^{g_+}$		12.9 ± 29.2
$a_0^{g_0}$	0.71 ± 0.03	0.72 ± 0.04
$a_1^{g_0}$	-2.86 ± 0.44	-2.80 ± 0.53
$a_2^{g_0}$	11.8 ± 2.47	11.7 ± 4.74
$a_3^{g_0}$		1.35 ± 29.4

Endpoint relation for baryons [JHEP11(2021)073].

Approximation in experimental measurement:

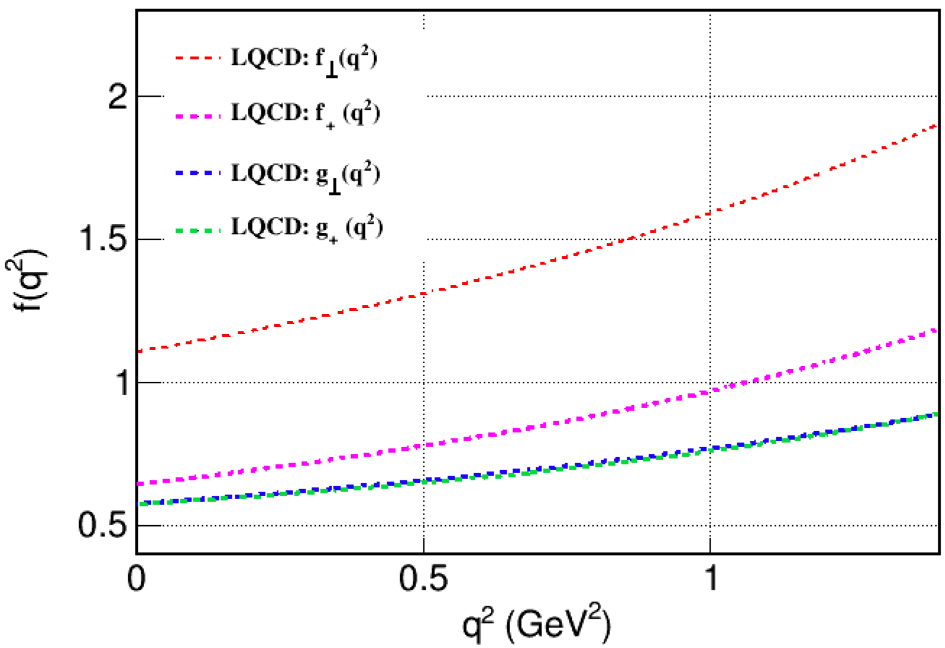
- In LQCD, 11 independent variables parameterized in four form factors.
- About 1200 events are collected from experiment.

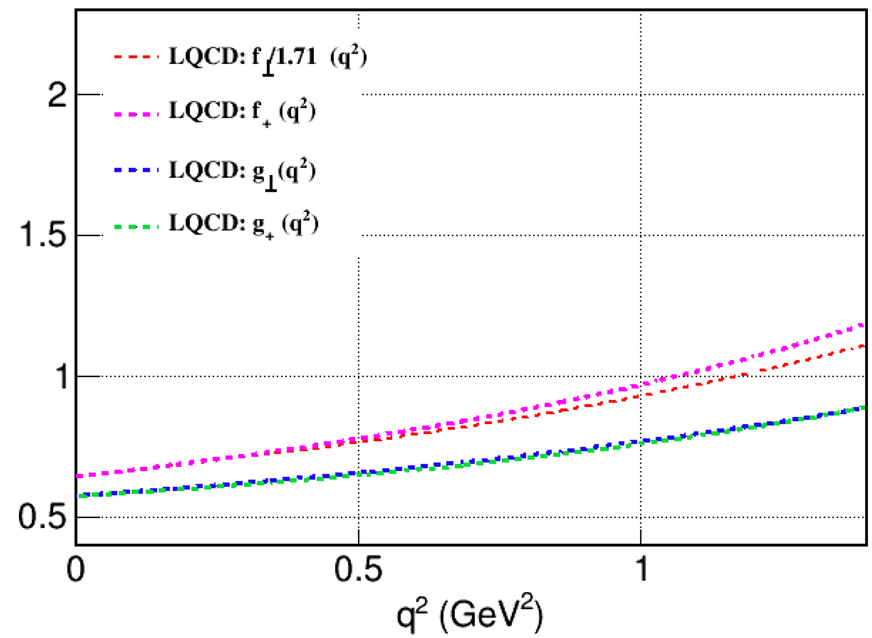


	Nominal fit
$a_0^{f_\perp}$	1.30 ± 0.06
$a_1^{f_\perp}$	-3.27 ± 1.18
$a_2^{f_\perp}$	7.16 ± 11.6
$a_3^{f_\perp}$	
$a_0^{f_+}$	0.81 ± 0.03
$a_1^{f_+}$	-2.89 ± 0.52
$a_2^{f_+}$	7.82 ± 4.53
$a_3^{f_+}$	
$a_0^{f_0}$	0.77 ± 0.02
$a_1^{f_0}$	-2.24 ± 0.51
$a_2^{f_0}$	5.38 ± 4.80
$a_3^{f_0}$	
$a_0^{g_\perp,g_+}$	0.68 ± 0.02
$a_1^{g_\perp}$	-1.91 ± 0.35
$a_2^{g_\perp}$	6.24 ± 4.89
$a_3^{g_\perp}$	
$a_1^{g_+}$	-2.44 ± 0.25
$a_2^{g_+}$	13.7 ± 2.15
$a_3^{g_+}$	
$a_0^{g_0}$	0.71 ± 0.03
$a_1^{g_0}$	-2.86 ± 0.44
$a_2^{g_0}$	11.8 ± 2.47
$a_3^{g_0}$	

$$f(q^2) = \frac{1}{1 - q^2/(m_{\rm pole}^f)^2} \sum_{n=0}^{n_{\rm max}} a_n^f [z(q^2)]^n \;\Rightarrow\; f(q^2) = \frac{a_0^f}{1 - q^2/(m_{\rm pole}^f)^2} [1 + \alpha_1^f \times z(q^2)]$$

$$f(q^2) = \frac{1}{1-q^2/(m_{\rm pole}^f)^2} [a_0^f + a_1^f \cdot z(q^2) + a_2^f \cdot z^2(q^2)]$$





$$
\begin{aligned}
f_\perp(q^2) &= \frac{a_0^{f_\perp}}{1-q^2/(m_{\rm pole}^{f_\perp})^2}[1+\alpha_1^{f_\perp}\cdot z(q^2)],\\
f_+(q^2) &= \frac{a_0^{f_+}}{1-q^2/(m_{\rm pole}^{f_+})^2}[1+\alpha_1^{f_+}\cdot z(q^2)],\\
g_\perp(q^2) &= \frac{a_0^{g_\perp}}{1-q^2/(m_{\rm pole}^{g_\perp})^2}[1+\alpha_1^{g_\perp}\cdot z(q^2)],\\
g_+(q^2) &= \frac{a_0^{g_+}}{1-q^2/(m_{\rm pole}^{g_+})^2}[1+\alpha_1^{g_+}\cdot z(q^2)].
\end{aligned}
$$

$$
\begin{aligned}
f_\perp(q^2) &= \frac{r_{f_\perp}\times a_0^{g_\perp}}{1-q^2/(m_{\rm pole}^{f_\perp})^2}[1+a_1^{f_\perp}\cdot z(q^2)],\\
f_+(q^2) &= \frac{r_{f_+}\times a_0^{g_\perp}}{1-q^2/(m_{\rm pole}^{f_+})^2}[1+a_1^{f_\perp}\cdot z(q^2)],\\
g_\perp(q^2) &= \frac{a_0^{g_\perp}}{1-q^2/(m_{\rm pole}^{g_\perp})^2}[1+a_1^{g_\perp}\cdot z(q^2)],\\
g_+(q^2) &= \frac{r_{g_+}\times a_0^{g_\perp}}{1-q^2/(m_{\rm pole}^{g_\perp})^2}[1+a_1^{g_\perp}\cdot z(q^2)].
\end{aligned}
$$

- The free parameters are reduced from 11 to 6 in anaysis, which are:

$$a_0^{g_\perp},\quad \alpha_1^{g_\perp},\quad \alpha_1^{f_\perp},\quad r_{f_\perp}=a_0^{f_\perp}/a_0^{g_\perp},\quad r_{f_+}=a_0^{f_+}/a_0^{g_\perp},\quad r_{g_+}=a_0^{g_+}/a_0^{g_\perp}$$

Study of the kinematics in $\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$ decay:

$$\frac{d^4\Gamma}{dq^2 d\cos\theta_e d\cos\theta_p d\chi} = \frac{G_F^2|V_{cs}|^2}{2(2\pi)^4}\cdot\frac{Pq^2}{24M_{\Lambda_c}^2}\left\{\frac{3}{8}(1-\cos\theta_e)^2|H_{\frac{1}{2}1}|^2(1+\alpha_\Lambda\cos\theta_p)+\frac{3}{8}(1+\cos\theta_e)^2|H_{-\frac{1}{2}-1}|^2(1-\alpha_\Lambda\cos\theta_p)\right.$$
$$+\frac{3}{4}\sin^2\theta_e[|H_{\frac{1}{2}0}|^2(1+\alpha_\Lambda\cos\theta_p)+|H_{-\frac{1}{2}0}|^2(1-\alpha_\Lambda\cos\theta_p)]+\frac{3}{2\sqrt{2}}\alpha_\Lambda\cos\chi\sin\theta_e\sin\theta_p$$
$$\left.\times[(1-\cos\theta_e)H_{-\frac{1}{2}0}H_{\frac{1}{2}1}+(1+\cos\theta_e)H_{\frac{1}{2}0}H_{-\frac{1}{2}-1}]\right\}$$

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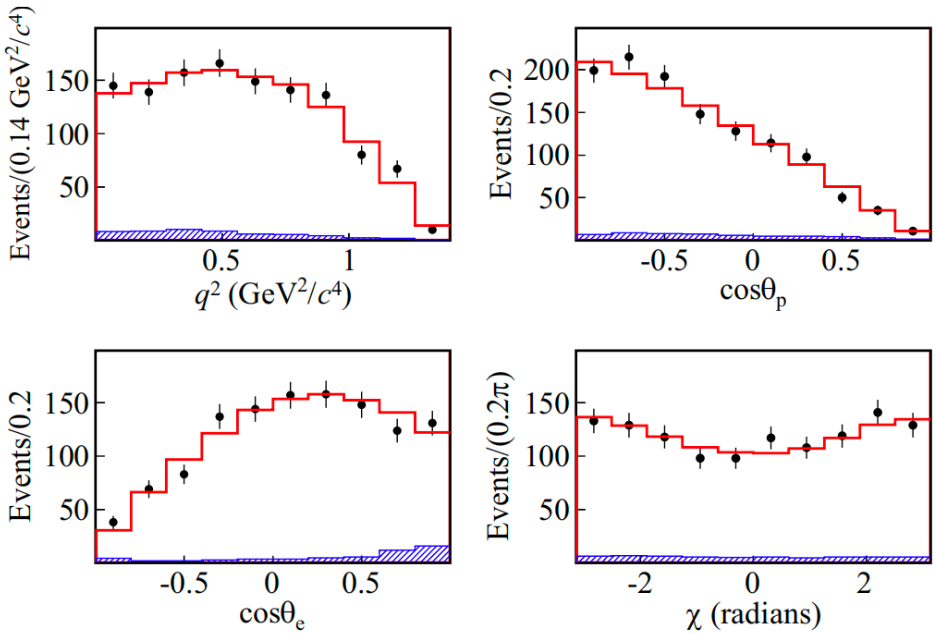
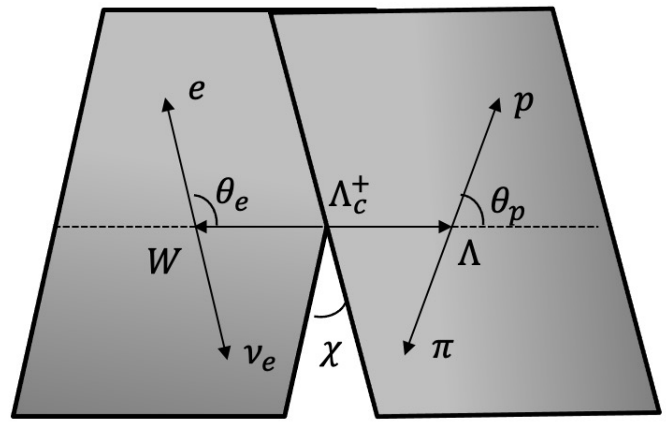


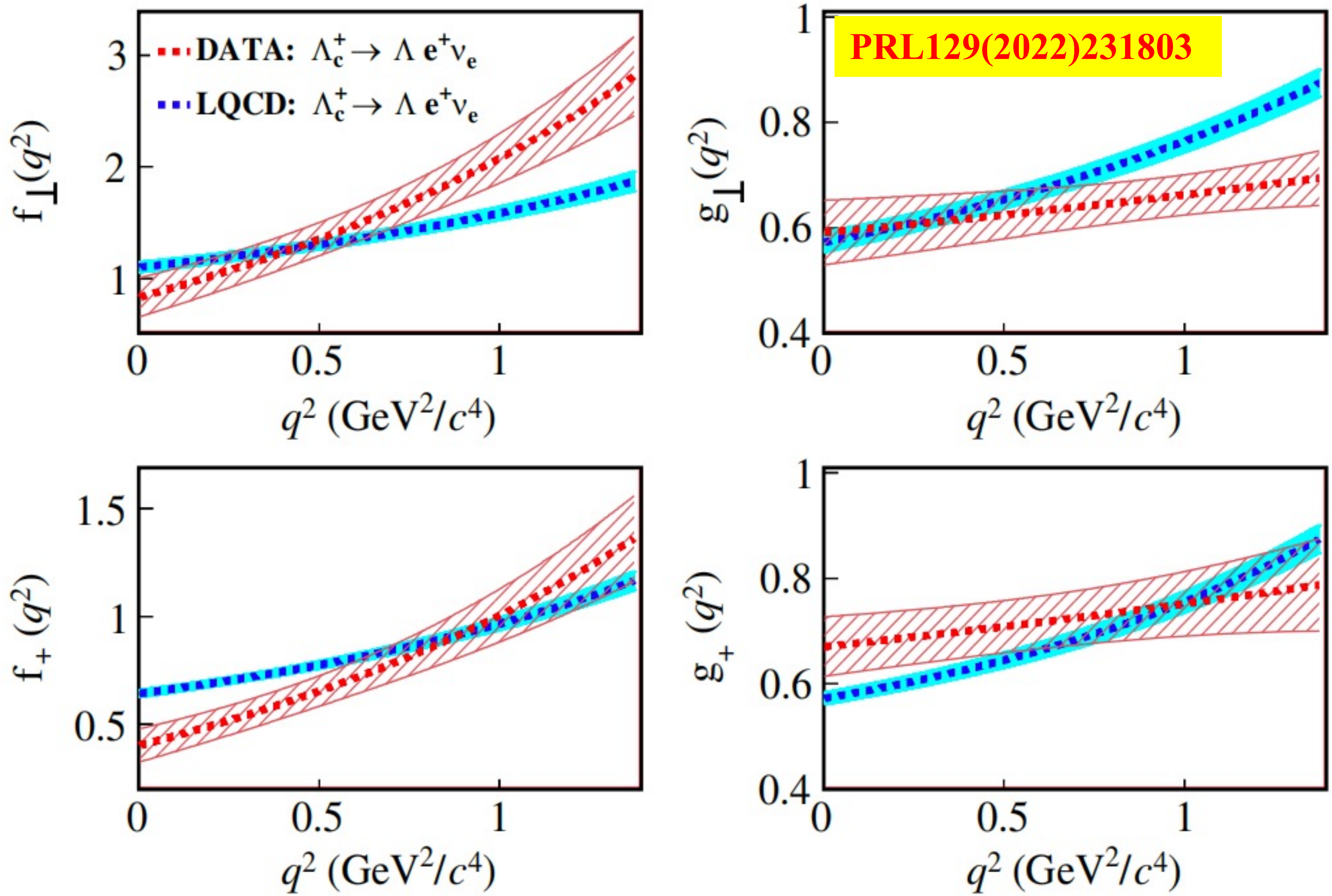


Parameters	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
Values	$1.43 \pm 2.09 \pm 0.16$	$-8.15 \pm 1.58 \pm 0.05$	$1.75 \pm 0.32 \pm 0.01$	$3.62 \pm 0.65 \pm 0.02$	$1.13 \pm 0.13 \pm 0.01$
Coefficients	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
$a_0^{g_\perp}$	−0.64	0.60	−0.66	−0.83	−0.40
$\alpha_1^{g_\perp}$		−0.63	0.62	0.53	−0.33
$\alpha_1^{f_\perp}$			−0.79	−0.67	−0.07
r_{f_+}				0.57	−0.09
$r_{f_\perp}$					0.39

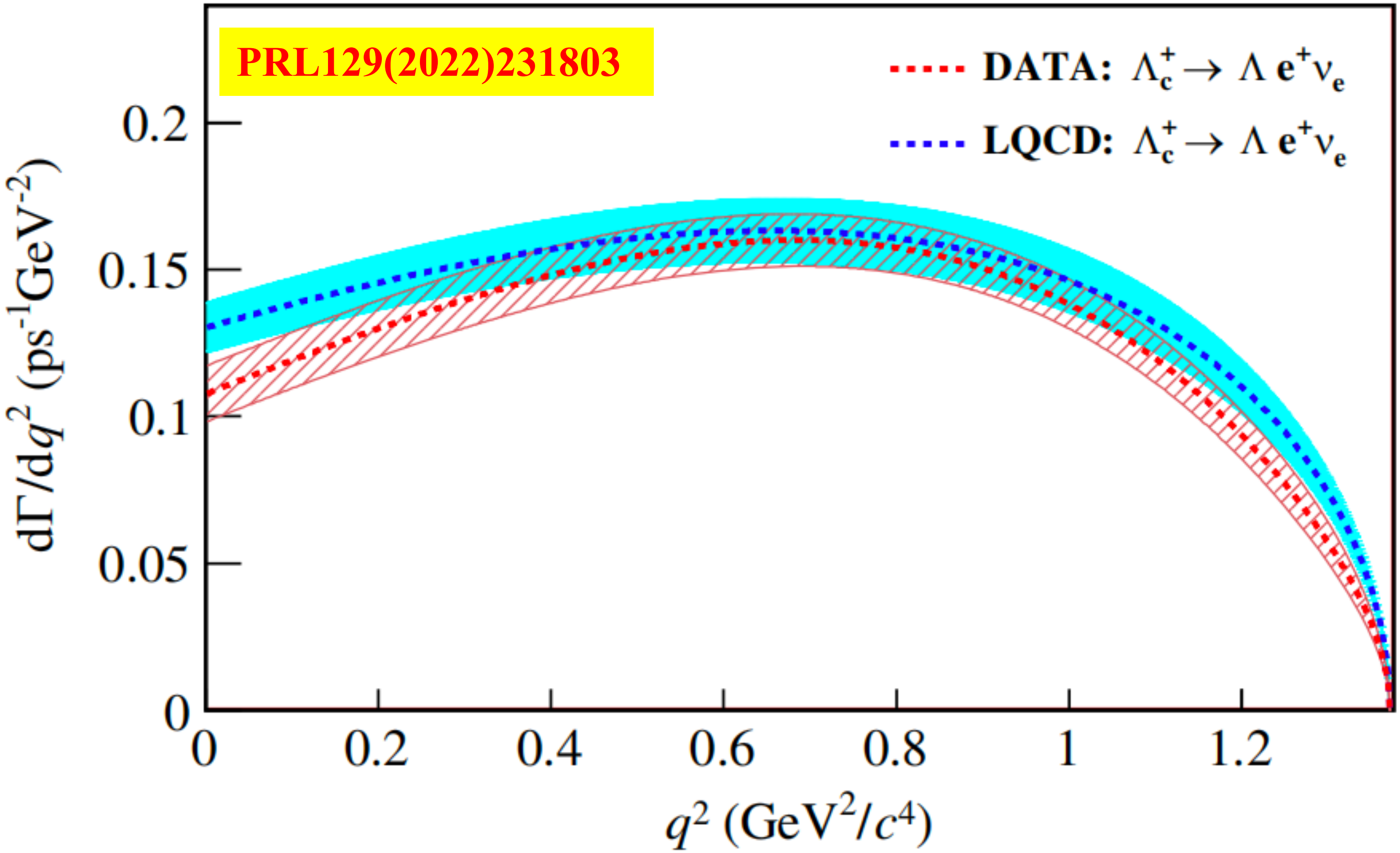
- Helicity amplitude:

$$H^V_{\frac{1}{2}1} = \sqrt{2Q_-}f_\perp(q^2), \qquad H^A_{\frac{1}{2}1} = \sqrt{2Q_+}g_\perp(q^2),$$
$$H^V_{\frac{1}{2}0} = \sqrt{Q_-/q^2}f_+(q^2)(M_{\Lambda_c}+M_\Lambda),$$
$$H^A_{\frac{1}{2}0} = \sqrt{Q_+/q^2}g_+(q^2)(M_{\Lambda_c}-M_\Lambda),$$

Comparisons between data and LQCD prediction



Comparisons between data and LQCD prediction



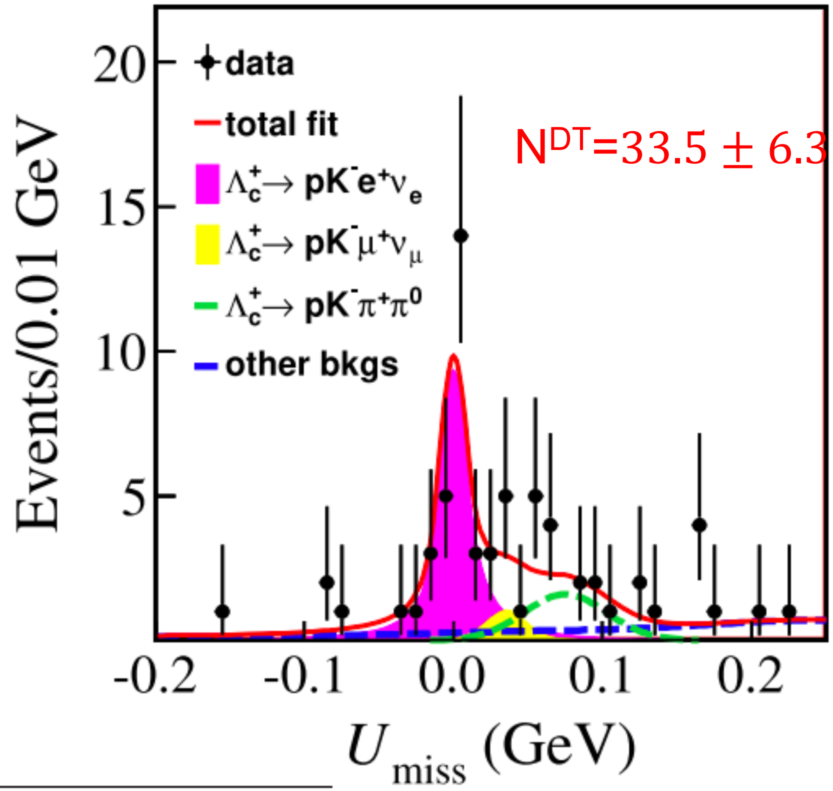
Observation of $\Lambda_c^+ \to pK^-e^+\nu_e$

Phys. Rev. D 106, 112010 (2023)

- The new observed SL decay mode:

  $BF(\Lambda_c^+ \to pK^- e^+ \nu_e) = (0.88 \pm 0.15 \pm 0.07) \times 10^{-3}$

  Significance: 8.2σ



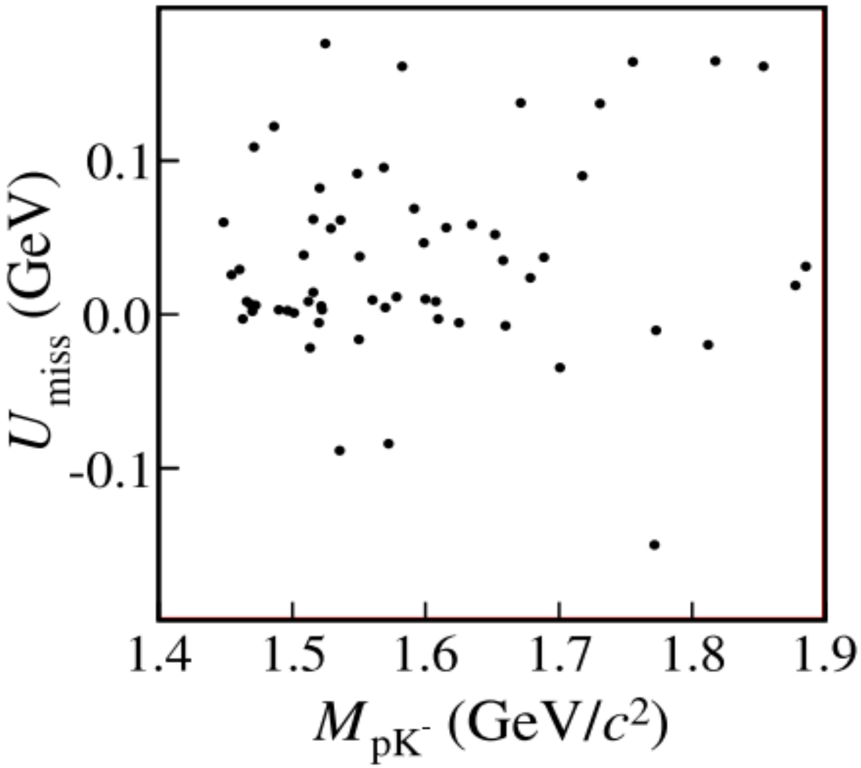
- This work provide a clear confirmation that the SL Λ_c^+ decays are not saturated by the $\Lambda \ell^+ \nu_\ell$ final state.

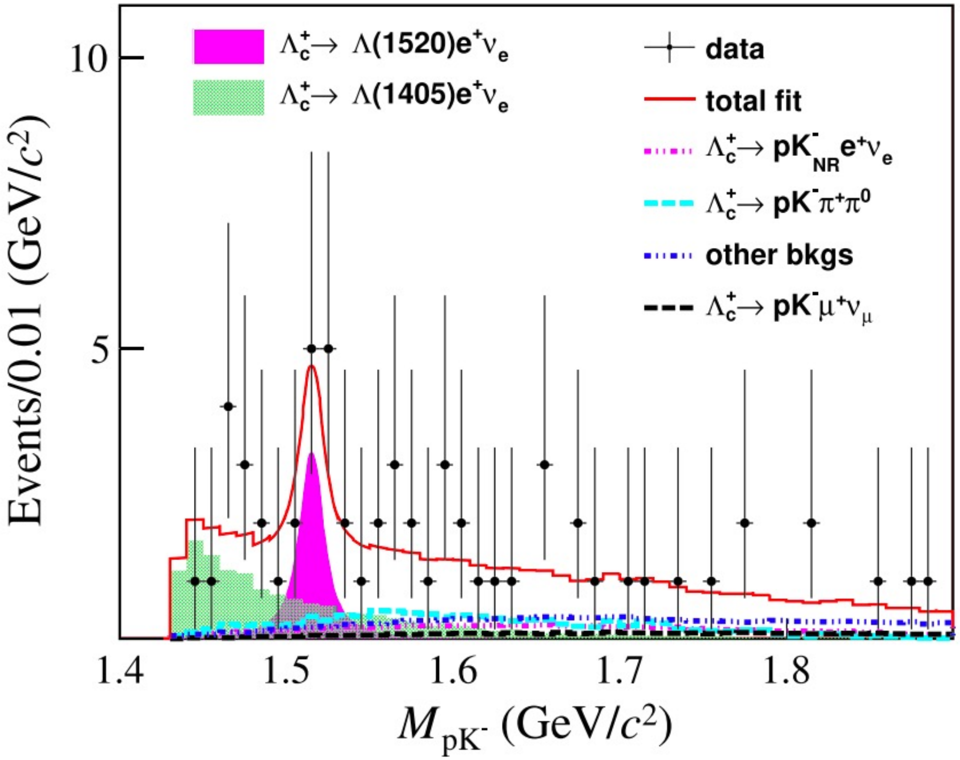
- Study of pK^- mass spectrum can be used to understand the nature of excited Λ^* states.

	$\mathcal{B}(\Lambda_c^+ \to \Lambda(1520)e^+\nu_e)$	$\mathcal{B}(\Lambda_c^+ \to \Lambda(1405)e^+\nu_e)$
Constituent quark model [8]	1.01	3.04
Molecular state [9]	...	0.02
Nonrelativistic quark model [10]	0.60	2.43
Lattice QCD [12,13]	0.512 ± 0.082	...
Measurement	$1.02 \pm 0.52 \pm 0.11$	$\frac{0.42 \pm 0.19 \pm 0.04}{\mathcal{B}(\Lambda(1405) \to pK^-)}$

Evidence of $\Lambda_c^+ \rightarrow \Lambda^*(\rightarrow pK^-)e^+\nu_e$

Phys. Rev. D 106, 112010 (2023)



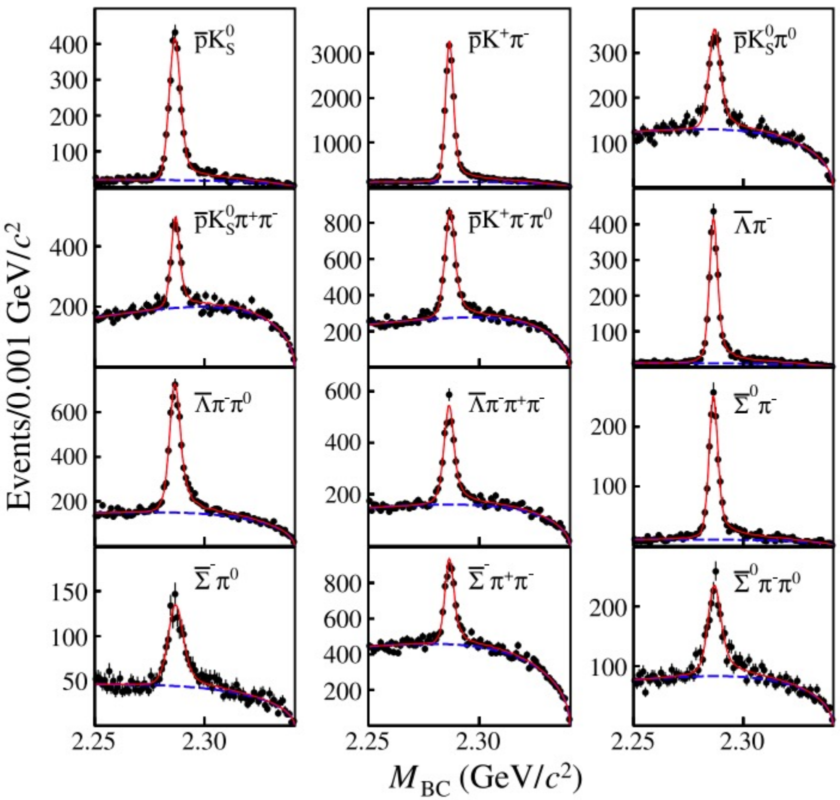


$\mathrm{BF}(\Lambda_c^+ \rightarrow \Lambda(1520)[\rightarrow pK^-]e^+\nu_e) = (0.23 \pm 0.12 \pm 0.02)\times10^{-3}$ 信号显著性 3.3σ

$\mathrm{BF}(\Lambda_c^+ \rightarrow \Lambda(1405)[\rightarrow pK^-]e^+\nu_e) = (0.42 \pm 0.19 \pm 0.04)\times10^{-3}$ 信号显著性 3.2σ

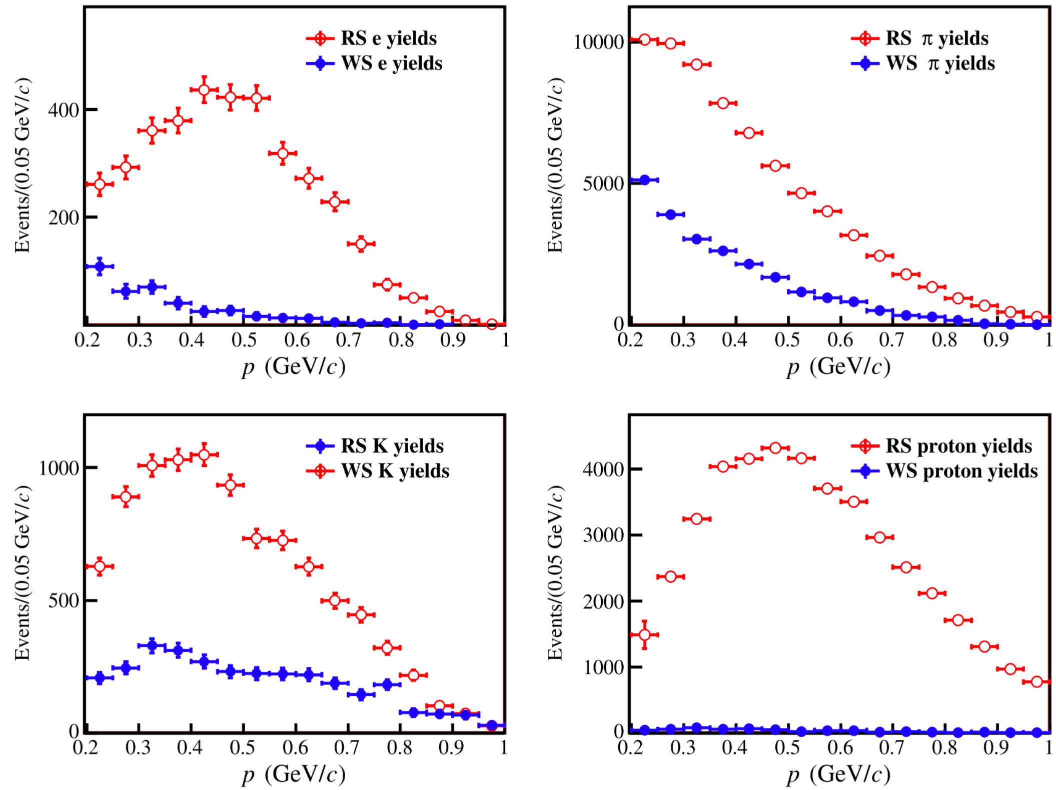
Inclusive SL decay $\Lambda_c^+ \rightarrow e^+X$

- 12 STs are used in this analysis



$\mathrm{N^{ST}} = 115437 \pm 446$

- DT yields: *Phys. Rev. D 107, 052005 (2023)*

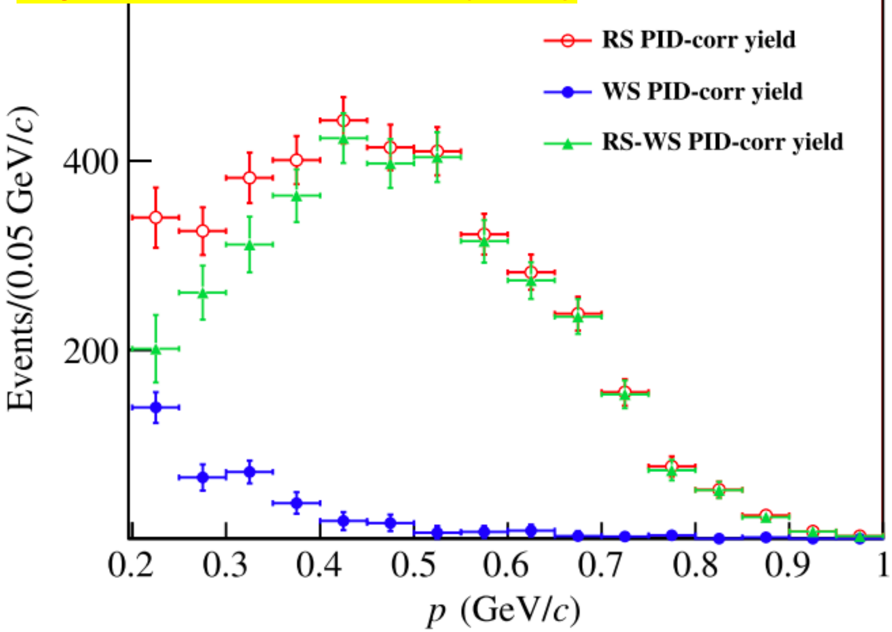


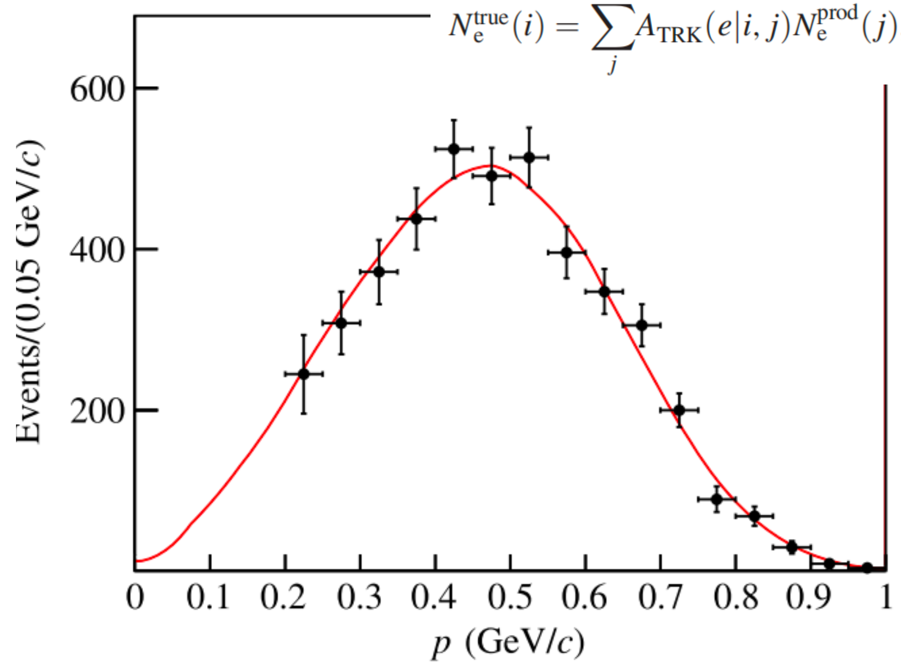
✓ Unfolding method to obtain true signal yields. The matrix can be obtained using selected control samples.

$$\begin{bmatrix} N_e^{\rm obs} \\ N_\pi^{\rm obs} \\ N_K^{\rm obs} \\ N_p^{\rm obs} \end{bmatrix} = \begin{bmatrix} P_{e\to e} & P_{\pi\to e} & P_{K\to e} & P_{p\to e} \\ P_{e\to\pi} & P_{\pi\to\pi} & P_{K\to\pi} & P_{p\to\pi} \\ P_{e\to K} & P_{\pi\to K} & P_{K\to K} & P_{p\to K} \\ P_{e\to p} & P_{\pi\to p} & P_{K\to p} & P_{p\to p} \end{bmatrix} \begin{bmatrix} N_e^{\rm true} \\ N_\pi^{\rm true} \\ N_K^{\rm true} \\ N_p^{\rm true} \end{bmatrix}$$

Inclusive SL decay $\Lambda_c^+ \rightarrow e^+X$

Phys. Rev. D 107, 052005 (2023)





Correction (see text)	RS yields	WS yields
Observed yields	3706 ± 71	394 ± 31
PID unfolding yields	3865 ± 80	376 ± 33
WS subtraction	3489 ± 87	
Tracking unfolding yields	4333 ± 107	
Extrapolation	4692 ± 117	

$\mathrm{BF}(\Lambda_c^+ \rightarrow \mathrm{X}e^+\nu_e) = (4.06 \pm 0.10 \pm 0.09)\%$

The precision is improved by threefold.

$$\frac{\Gamma(\Lambda_c^+ \rightarrow \mathrm{X}e^+\nu_e)}{\Gamma(D_s^+ \rightarrow \mathrm{X}e^+\nu_e)} = 1.28 \pm 0.05$$

$\mathrm{BF}(\Lambda_c^+ \rightarrow \mathrm{X}e^+\nu_e) = (4.06 \pm 0.10 \pm 0.09)\%$

$\mathrm{BF}(\Lambda_c^+ \rightarrow \Lambda e^+\nu_e) = (3.56 \pm 0.11 \pm 0.07)\%$

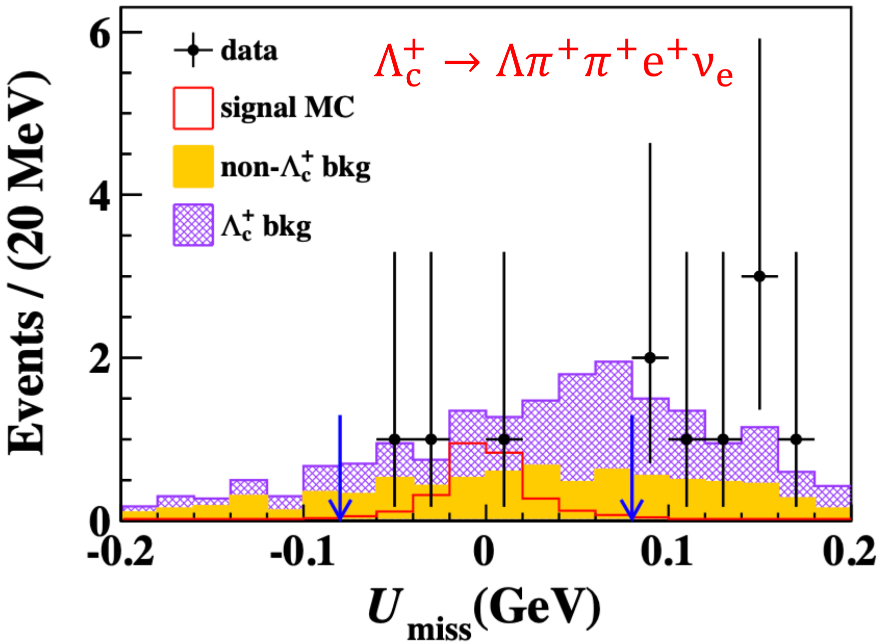
$\mathrm{BF}(\Lambda_c^+ \rightarrow pK^- e^+\nu_e) = (0.88 \pm 0.15 \pm 0.07)\times 10^{-3}$

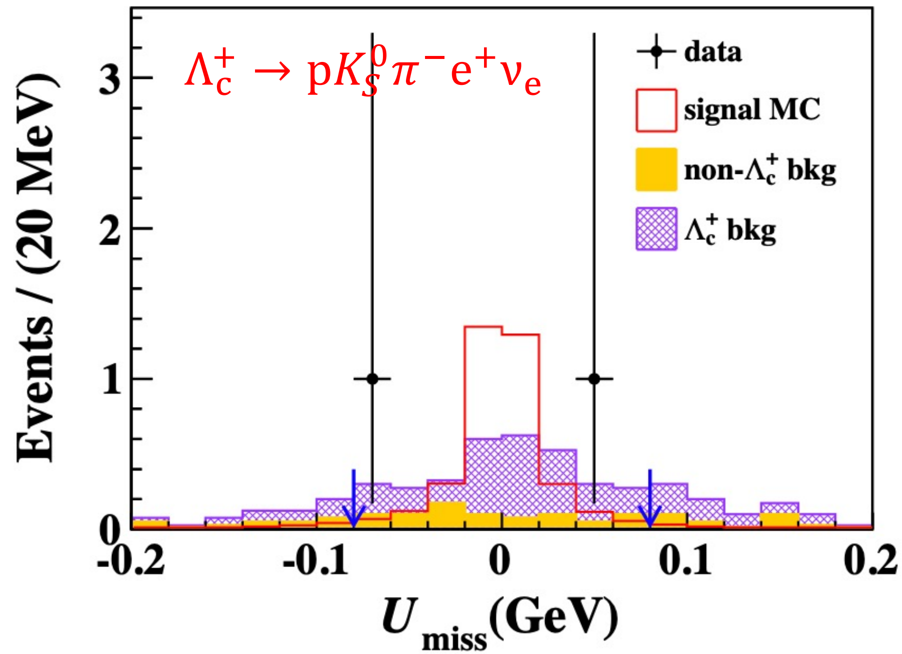
Unknown decay: 0.5%

Search for $\Lambda_c^+ \rightarrow \Lambda\pi^+\pi^-e^+\nu_e$ and $\Lambda_c^+ \rightarrow pK_s^0\pi^-e^+\nu_e$

- Searches for SL decay modes using 4.5/fb data

arXiv: 2302.07529





$\mathrm{BF}(\Lambda_c^+ \rightarrow \Lambda\pi^+\pi^+e^+\nu_e) < 3.9\times10^{-4}$

$\mathrm{BF}\left(\Lambda_c^+ \rightarrow pK_S^0\pi^-e^+\nu_e\right) < 3.3\times10^{-4}$

Decay mode	N^{obs}	$\varepsilon^{\mathrm{sig}}$ (%)	$N^{\mathrm{SB}}_{\mathrm{bkg1}}$	$N^{\mathrm{MC}}_{\mathrm{bkg2}} \pm \sigma^{\mathrm{MC}}_{\mathrm{bkg2}}$	N^{DT}
$\Lambda_c^+ \rightarrow \Lambda\pi^+\pi^-e^+\nu_e$	3	9.69 ± 0.03	9	4.8 ± 0.4	2.9
$\Lambda_c^+ \rightarrow pK_S^0\pi^-e^+\nu_e$	2	13.58 ± 0.02	0	2.2 ± 0.3	3.8

Upper limits at 90% C.L.

- The BFs are set at 90% C.L. for the two decays.

Summary

- Recent results on Λ_c^+ SL decays at BESIII are reported.

- In addition to these published/submitted papers, some other works are also ongoing with good status. Such as:

$$\Lambda_c^+ \to n e^+ \nu_e, \quad \Lambda_c^+ \to \Sigma \pi e^+ \nu_e, \quad \Lambda_c^+ \to \Lambda \mu^+ \nu_\mu$$

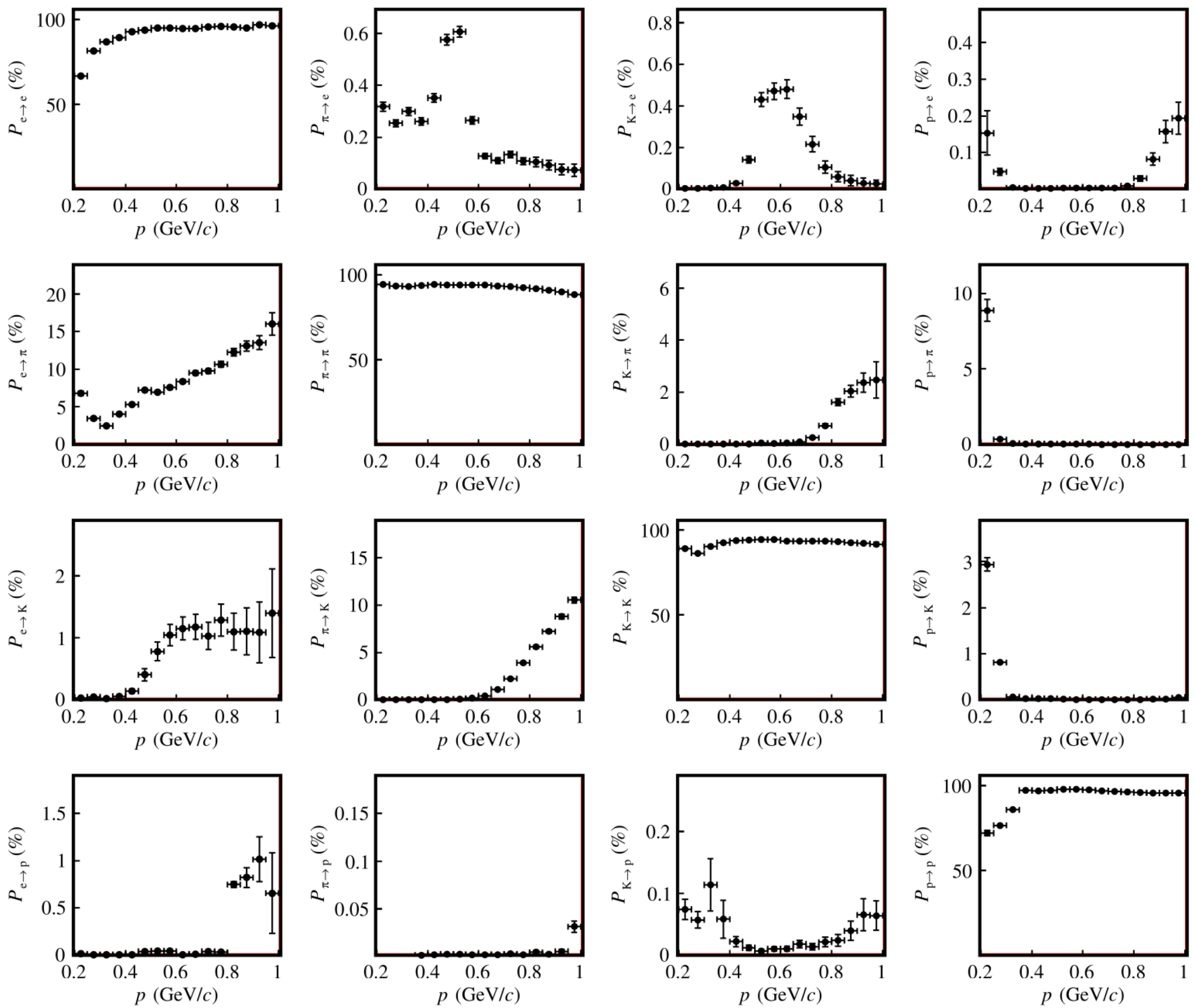
- More works will be reported in the future.

THANKS!

Thanks!

✓ Unfolding method to obtain true signal yields:

$$
\begin{bmatrix} N_e^{\mathrm{obs}} \\ N_\pi^{\mathrm{obs}} \\ N_K^{\mathrm{obs}} \\ N_p^{\mathrm{obs}} \end{bmatrix}
=
\begin{bmatrix}
P_{e\to e} & P_{\pi\to e} & P_{K\to e} & P_{p\to e} \\
P_{e\to \pi} & P_{\pi\to \pi} & P_{K\to \pi} & P_{p\to \pi} \\
P_{e\to K} & P_{\pi\to K} & P_{K\to K} & P_{p\to K} \\
P_{e\to p} & P_{\pi\to p} & P_{K\to p} & P_{p\to p}
\end{bmatrix}
\begin{bmatrix} N_e^{\mathrm{true}} \\ N_\pi^{\mathrm{true}} \\ N_K^{\mathrm{true}} \\ N_p^{\mathrm{true}} \end{bmatrix}
$$



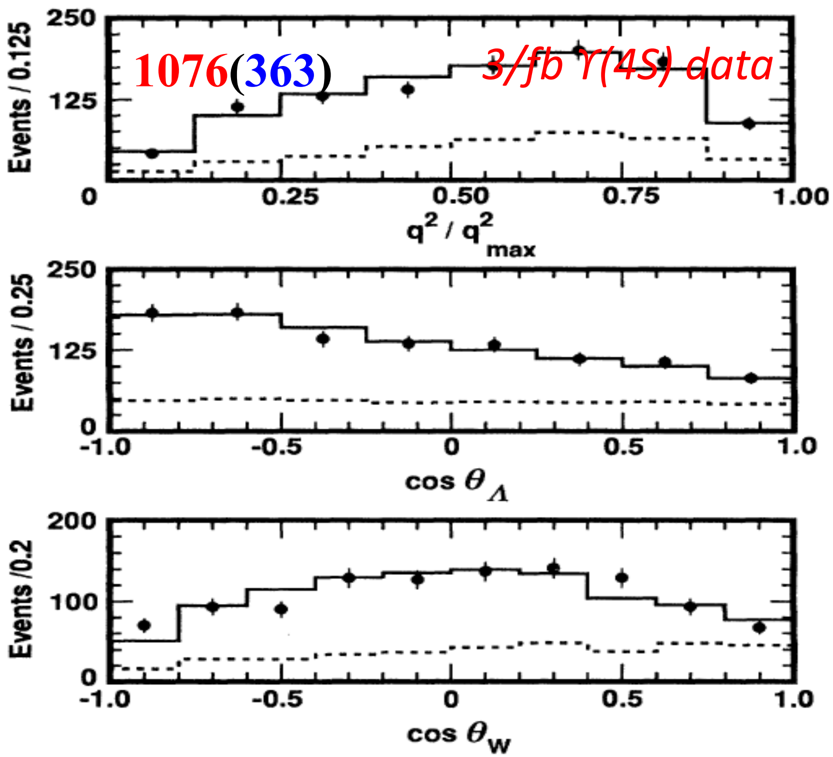
Previous FF measurements in $\Lambda_c^+ \to \Lambda e^+ \nu_e$

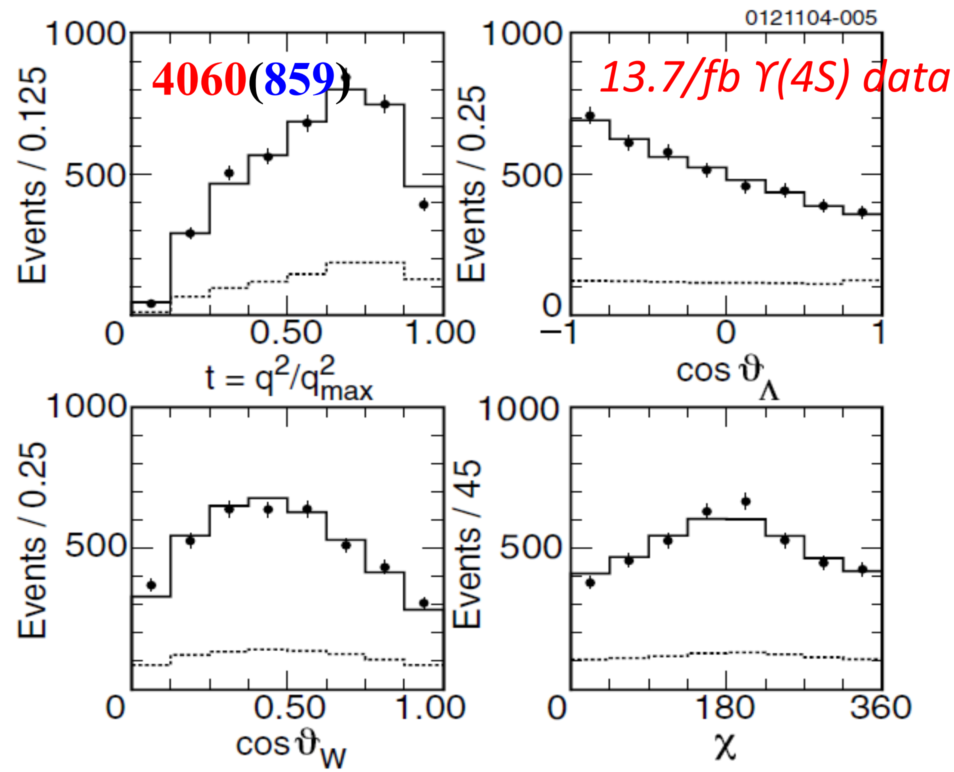
- *Previous Measurements from CLEO.*

$$F_1^V(q^2) = -F_1^A(q^2) = f_1(q^2) + \frac{M_\Lambda}{M_{\Lambda_c}} f_2(q^2)$$

$$F_2^V(q^2) = -F_2^A(q^2) = \frac{1}{M_{\Lambda_c}} f_2(q^2)$$

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

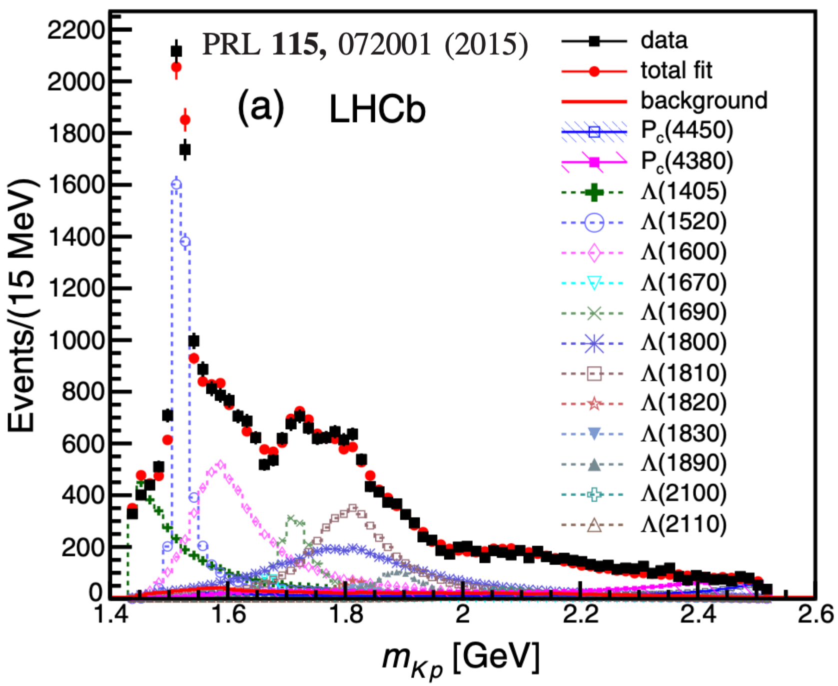


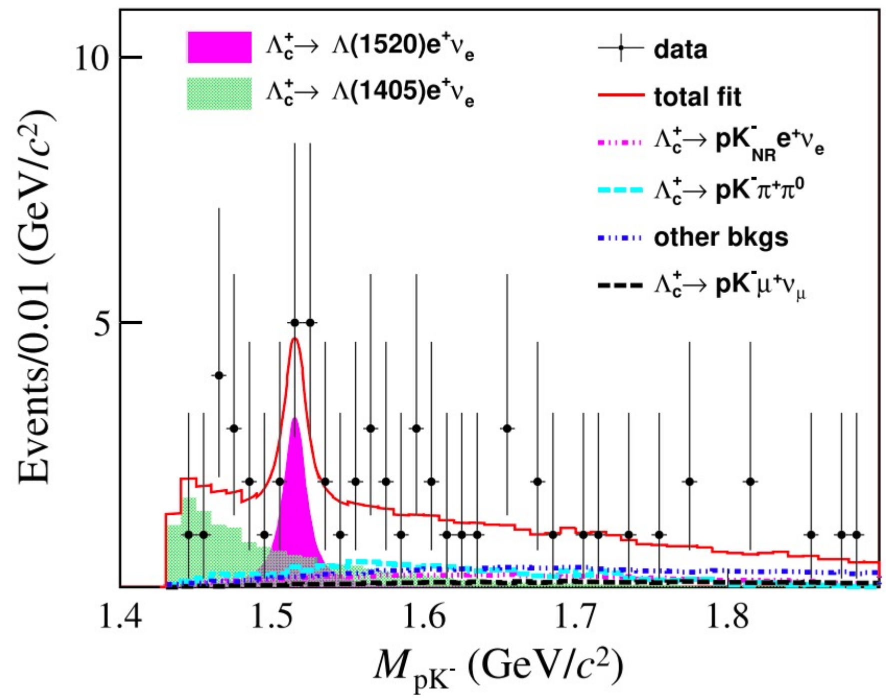


f_2/f_1=-0.25±0.14±0.08 (64%)

f_2/f_1=-0.31±0.05±0.04 (21%)

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


PRL 115, 072001 (2015)
(a) LHCb
data
total fit
background
P_c(4450)
P_c(4380)
Λ(1405)
Λ(1520)
Λ(1600)
Λ(1670)
Λ(1690)
Λ(1800)
Λ(1810)
Λ(1820)
Λ(1830)
Λ(1890)
Λ(2100)
Λ(2110)
Events/(15 MeV)
m_Kp [GeV]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
1.4
1.6
1.8
2
2.2
2.4
2.6


Λc+→ Λ(1520)e+νe
Λc+→ Λ(1405)e+νe
data
total fit
Λc+→ pK-NR e+νe
Λc+→ pK-π+π0
other bkgs
Λc+→ pK-μ+νμ
Events/0.01 (GeV/c2)
M_pK- (GeV/c2)
10
5
1.4
1.5
1.6
1.7
1.8