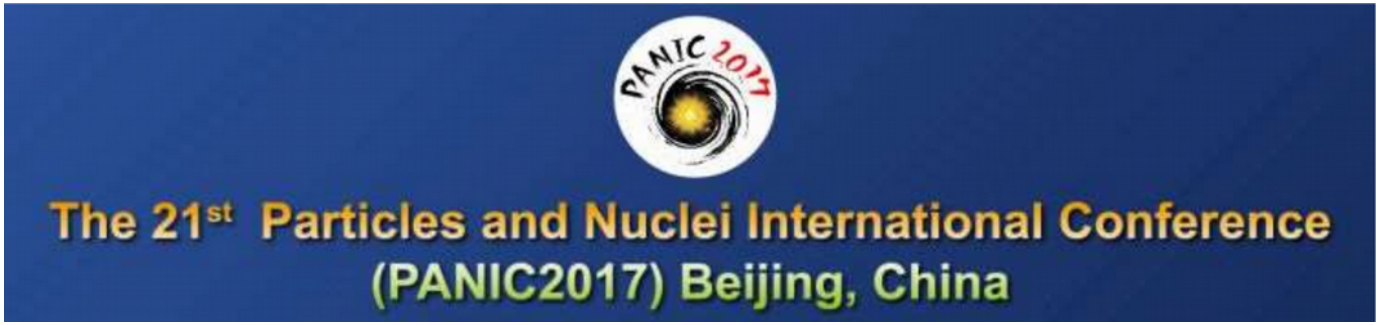

Λ_c physics at BESIII

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On behalf of the BESIII Collaboration

INFN
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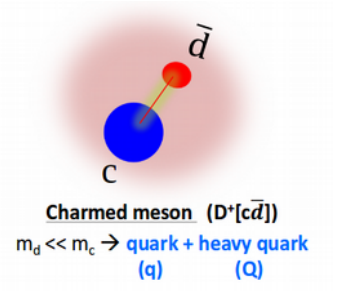
PANIC2017 – CCNC, Beijing

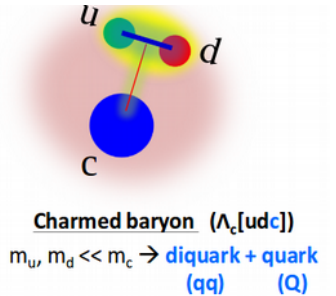
Outline

- Λ_c features in modern HEP
- BESIII, BEPCII and data
  - Analysis at thresholds
- Discussion of the most interesting results
  - First Direct Measurement of Λ_c BF at threshold
  - $\Lambda_c \rightarrow n K^0_S \pi^+$
  - $\Lambda_c \rightarrow p\eta$ e $\Lambda_c \rightarrow p\pi^0$
  - $\Lambda_c \rightarrow \Sigma^- \pi^+ \pi^+$ and $\Lambda_c \rightarrow \Sigma^- \pi^+ \pi^+ \pi^0$
  - Cross section at threshold
- Future plans at BESIII

Charmed baryon

- Study of charmed baryons allows to study Heavy quark - quark internal dynamics with a complementary view with respect to the charmed mesons
- Λ_c is extremely powerful system to be tested
  - Heavy Quark Effective Theory models as a heavy quark coupled with a unexcited spin zero diquark

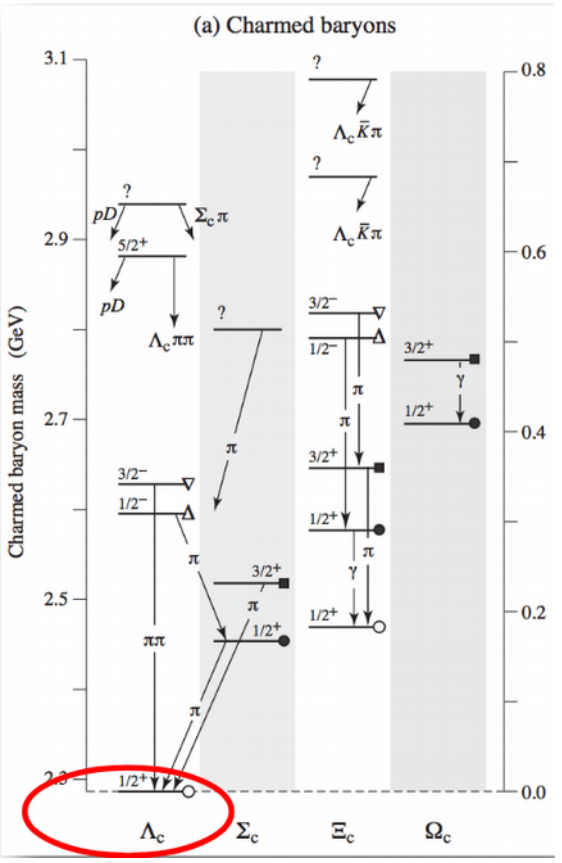




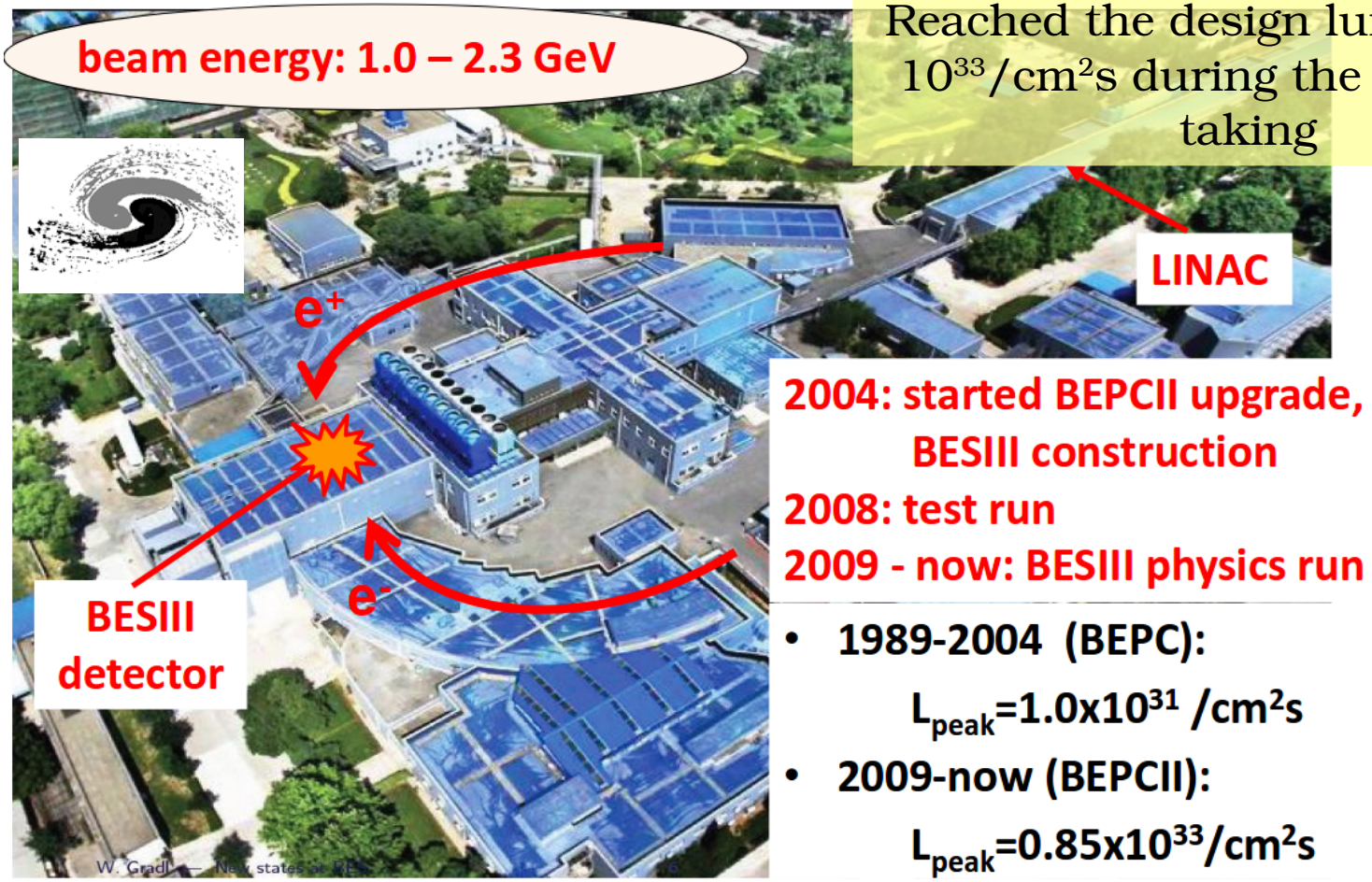
  - Absence of degree of freedom of spin and isospin in the light quark component makes the prediction more reliable
  - Diquark correlation is enhanced by the weak Color Magnetic Interaction with a heavy quark

More features of the Λ_c

- Λ_c is the lightest charmed baryon, so eventually all the other will decay into Λ_c
  - Important to know the decay properties
- Λ_c golden decay mode $\Lambda_c \rightarrow pK^-\pi^+$ is often used to normalize other BR
  - Very important to estimate the absolute BR
- Λ_b decays preferentially in Λ_c
  - Important input to B physics and V_{ub} calculations



BEPCII @ IHEP



Reached the design luminosity of $10^{33}/cm^2s$ during the 2016 data taking

2004: started BEPCII upgrade, BESIII construction

2008: test run

2009 - now: BESIII physics run

- **1989-2004 (BEPC):**

  $L_{peak}=1.0x10^{31}\ /cm^2s$

- **2009-now (BEPCII):**

  $L_{peak}=0.85x10^{33}/cm^2s$

BESIII @ IHEP

Time of Flight detector (TOF):

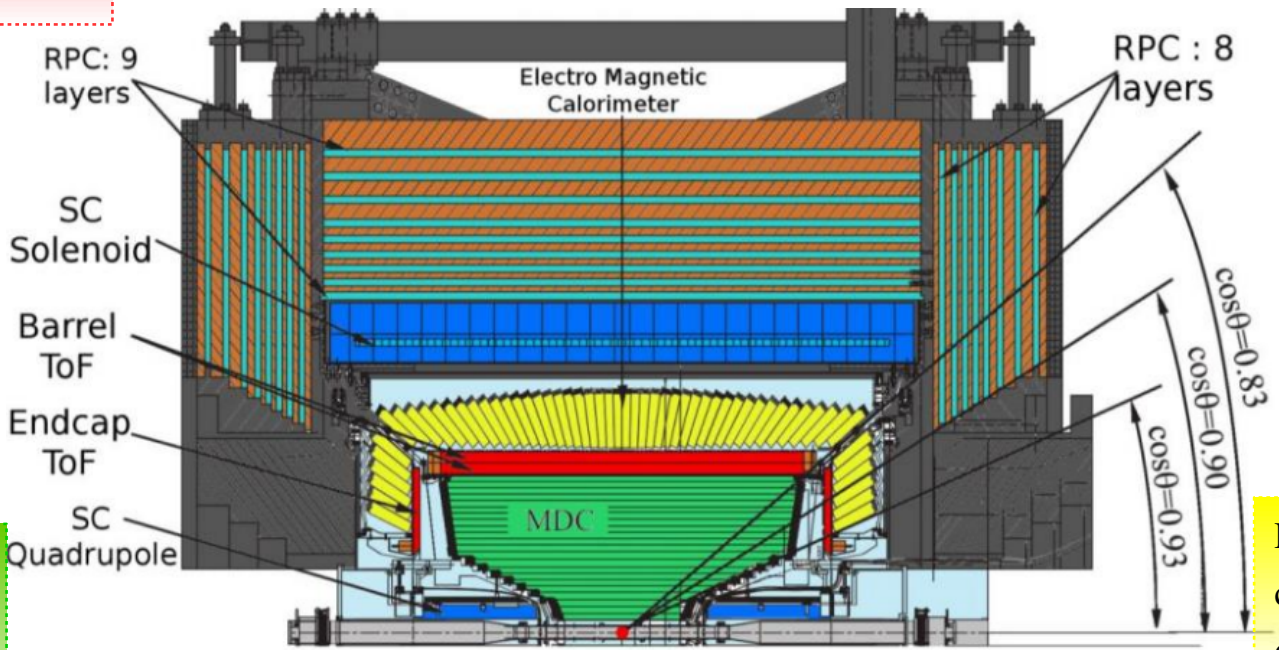
σ_t (barrel) = 90 ps

σ_t (endcap) = 110 ps

Axial magnetic field: 1 T

Muon Counters (RPCs):

$\delta_{r\phi}$ = 1.4 cm – 1.7 cm



Main Drift Chamber (MDC):

σ_x (1 GeV/c) ~ 130 um

dp/p (1 GeV/c) = 0.5 %

Electromagnetic calorimeter (ECAL):

$dE/\sqrt{E}$ (1 GeV) = 2.5 %

BESIII Λ_c program

- Started in 2014, with 4 energy values just above threshold
  - Great work of the accelerator people to increase the machine energy!

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

Roughly ~110000 $\Lambda_c\bar{\Lambda}_c$ just 26 MeV above threshold! (PRL 116, 052001 (2016))

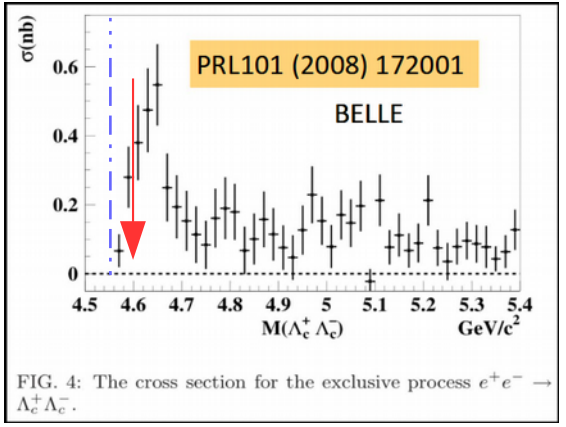


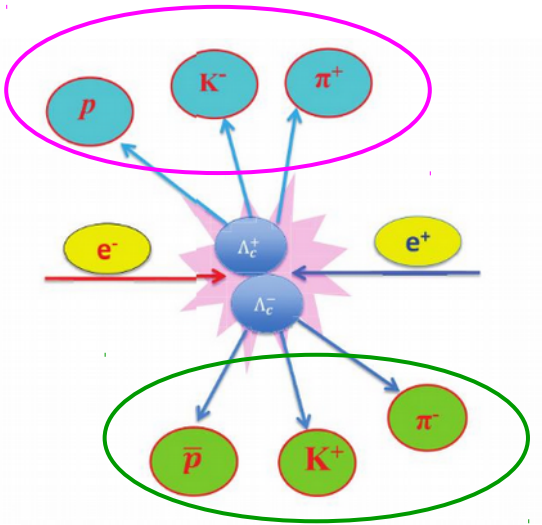
FIG. 4: The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

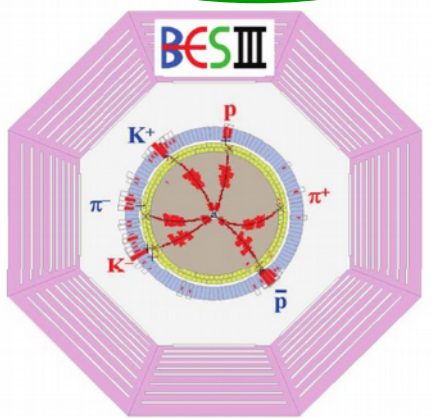
There are plans in the future to collect 3/fb data even at higher energies to expand the possibilities

Λ_c analysis at threshold

- At threshold, Λ_c are produced in pairs

- Typically two techniques are used to extract the yields of Λ_c
  - Single Tag: Only one Λ_c is reconstructed
    - Higher efficiency
    - Larger background
  - Double Tag: both Λ_c
    - Lower efficiency
    - Smaller background

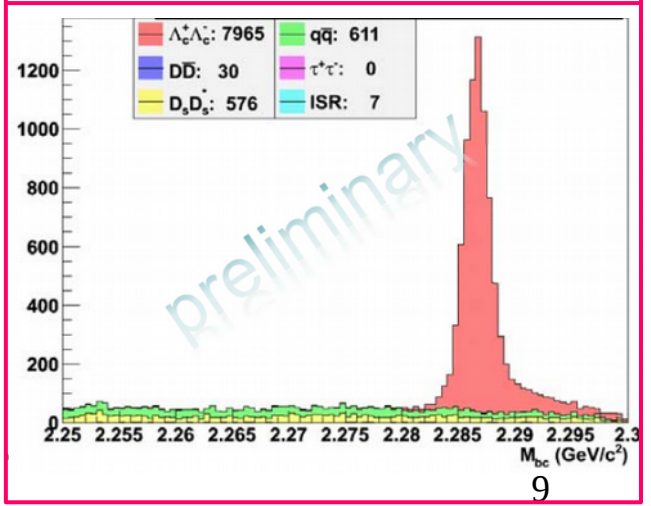




Λ_c analysis at threshold

- In ST studies frequently used variables:
  - Mass beam constrained: $M_{bc} = \sqrt{E_{beam}^2 - p_{candidate}^2}$
    - Asymmetric shape due to the ISR
      - $p_{candidate}$ becomes smaller
    - Resolution dominated by the energy spread of the beam (indipendently from the final states)
  - ΔE: $dE = E_{candidate} - E_{beam}$
    - mass difference between beam and candidates
    - Almost indipendent from the final state
- In DT studies:
  - U_{miss}:
    - Missing mass

Example of ST M_{bc}



Λ_c measurement at 2014

	Mode		Fraction (Γ_i/Γ)	Scale factor/ Confidence level
	Hadronic modes with a p: $S = -1$ final states			
Γ_1	$p\overline{K}^0$		(2.3 ± 0.6) %	
Γ_2	$pK^-\pi^+$	[a]	(5.0 ± 1.3) %	
Γ_3	$p\overline{K}^*(892)^0$	[b]	(1.6 ± 0.5) %	
Γ_4	$\Delta(1232)^{++}K^-$		(8.6 ± 3.0) × 10^{-3}	
Γ_5	$\Lambda(1520)\pi^+$	[b]	(1.8 ± 0.6) %	
Γ_6	$pK^-\pi^+$ nonresonant		(2.8 ± 0.8) %	
Γ_7	$p\overline{K}^0\pi^0$		(3.3 ± 1.0) %	
Γ_8	$p\overline{K}^0\eta$		(1.2 ± 0.4) %	
Γ_9	$p\overline{K}^0\pi^+\pi^-$		(2.6 ± 0.7) %	
Γ_{10}	$pK^-\pi^+\pi^0$		(3.4 ± 1.0) %	
Γ_{11}	$pK^*(892)^-\pi^+$	[b]	(1.1 ± 0.5) %	
Γ_{12}	$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$		(3.6 ± 1.2) %	
Γ_{13}	$\Delta(1232)\overline{K}^*(892)$		seen	
Γ_{14}	$pK^-\pi^+\pi^+\pi^-$		(1.1 ± 0.8) × 10^{-3}	
Γ_{15}	$pK^-\pi^+\pi^0\pi^0$		(8 ± 4) × 10^{-3}	
Γ_{16}	$pK^-\pi^+3\pi^0$			
	Hadronic modes with a p: $S = 0$ final states			
Γ_{17}	$p\pi^+\pi^-$		(3.5 ± 2.0) × 10^{-3}	
Γ_{18}	$pf_0(980)$	[b]	(2.8 ± 1.9) × 10^{-3}	
Γ_{19}	$p\pi^+\pi^+\pi^-\pi^-$		(1.8 ± 1.2) × 10^{-3}	
Γ_{20}	pK^+K^-		(7.7 ± 3.5) × 10^{-4}	
Γ_{21}	$p\phi$	[b]	(8.2 ± 2.7) × 10^{-4}	
Γ_{22}	pK^+K^- non-ϕ		(3.5 ± 1.7) × 10^{-4}	
	Hadronic modes with a hyperon: $S = -1$ final states			
Γ_{23}	$\Lambda\pi^+$		(1.07± 0.28) %	
Γ_{24}	$\Lambda\pi^+\pi^0$		(3.6 ± 1.3) %	
Γ_{25}	$\Lambda\rho^+$		< 5 %	CL=95%
Γ_{26}	$\Lambda\pi^+\pi^+\pi^-$		(2.6 ± 0.7) %	
Γ_{27}	$\Sigma(1385)^+\pi^+\pi^-$, $\Sigma^{*+}\to\Lambda\pi^+$		(7 ± 4) × 10^{-3}	
Γ_{28}	$\Sigma(1385)^-\pi^+\pi^+$, $\Sigma^{*-}\to\Lambda\pi^-$		(5.5 ± 1.7) × 10^{-3}	
Γ_{29}	$\Lambda\pi^+\rho^0$		(1.1 ± 0.5) %	
Γ_{30}	$\Sigma(1385)^+\rho^0$, $\Sigma^{*+}\to\Lambda\pi^+$		(3.7 ± 3.1) × 10^{-3}	
Γ_{31}	$\Lambda\pi^+\pi^+\pi^-$ nonresonant		< 8 × 10^{-3}	CL=90%
Γ_{32}	$\Lambda\pi^+\pi^+\pi^-\pi^0$ total		(1.8 ± 0.8) %	
Γ_{33}	$\Lambda\pi^+\eta$	[b]	(1.8 ± 0.6) %	
Γ_{34}	$\Sigma(1385)^+\eta$	[b]	(8.5 ± 3.3) × 10^{-3}	
Γ_{35}	$\Lambda\pi^+\omega$	[b]	(1.2 ± 0.5) %	
Γ_{36}	$\Lambda\pi^+\pi^+\pi^-\pi^0$, no η or ω		< 7 × 10^{-3}	CL=90%
Γ_{37}	$\Lambda K^+\overline{K}^0$		(4.7 ± 1.5) × 10^{-3}	S=1.2
Γ_{38}	$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Lambda\overline{K}^0$		(1.3 ± 0.5) × 10^{-3}	
Γ_{39}	$\Sigma^0\pi^+$		(1.05± 0.28) %	
Γ_{40}	$\Sigma^+\pi^0$		(1.00± 0.34) %	
Γ_{41}	$\Sigma^+\eta$		(5.5 ± 2.3) × 10^{-3}	
Γ_{42}	$\Sigma^+\pi^+\pi^-$		(3.6 ± 1.0) %	
Γ_{43}	$\Sigma^+\rho^0$		< 1.4 %	CL=95%
Γ_{44}	$\Sigma^-\pi^+\pi^+$		(1.7 ± 0.5) %	
Γ_{45}	$\Sigma^0\pi^+\pi^0$		(1.8 ± 0.8) %	
Γ_{46}	$\Sigma^0\pi^+\pi^+\pi^-$		(8.3 ± 3.1) × 10^{-3}	
Γ_{47}	$\Sigma^+\pi^+\pi^-\pi^0$		—	
Γ_{48}	$\Sigma^+\omega$	[b]	(2.7 ± 1.0) %	
Γ_{49}	$\Sigma^+K^+K^-$		(2.8 ± 0.8) × 10^{-3}	
Γ_{50}	$\Sigma^+\phi$	[b]	(3.1 ± 0.9) × 10^{-3}	
Γ_{51}	$\Xi(1690)^0K^+$, $\Xi^{*0}\to\Sigma^+K^-$		(8.1 ± 3.0) × 10^{-4}	
Γ_{52}	$\Sigma^+K^+K^-$ nonresonant		< 6 × 10^{-4}	CL=90%
Γ_{53}	Ξ^0K^+		(3.9 ± 1.4) × 10^{-3}	
Γ_{54}	$\Xi^-K^+\pi^+$		(5.1 ± 1.4) × 10^{-3}	
Γ_{55}	$\Xi(1530)^0K^+$	[b]	(2.6 ± 1.0) × 10^{-3}	
	Hadronic modes with a hyperon: $S = 0$ final states			
Γ_{56}	ΛK^+		(5.0 ± 1.6) × 10^{-4}	
Γ_{57}	$\Lambda K^+\pi^+\pi^-$		< 4 × 10^{-4}	CL=90%
Γ_{58}	Σ^0K^+		(4.2 ± 1.3) × 10^{-4}	
Γ_{59}	$\Sigma^0K^+\pi^+\pi^-$		< 2.1 × 10^{-4}	CL=90%
Γ_{60}	$\Sigma^+K^+\pi^-$		(1.7 ± 0.7) × 10^{-3}	
Γ_{61}	$\Sigma^+K^*(892)^0$	[b]	(2.8 ± 1.1) × 10^{-3}	
Γ_{62}	$\Sigma^-K^+\pi^+$		< 1.0 × 10^{-3}	CL=90%
	Doubly Cabibbo-suppressed modes			
Γ_{63}	$pK^+\pi^-$		< 2.3 × 10^{-4}	CL=90%
	Semileptonic modes			
Γ_{64}	$\Lambda\ell^+\nu_\ell$	[c]	(2.0 ± 0.6) %	
Γ_{65}	$\Lambda e^+\nu_e$		(2.1 ± 0.6) %	
Γ_{66}	$\Lambda\mu^+\nu_\mu$		(2.0 ± 0.7) %	

HTTP://PDG.LBL.GOV Page 3 Created: 8/21/2014 12:56

Extracted from PDG2014

- $\Delta(BR)/BR \geq 20\%$ for many final states
- No final state with neutron
- Less than 68% of total BR was measured

Starting point of BESIII program

Published measurements…

- $\Lambda_c \rightarrow \Lambda e \nu$ (PRL115, 221805 (2015))
- First Direct Measurement of Λ_c BF at threshold (PRL116 052001 (2016))
- $\Lambda_c \rightarrow pKK$ e $\Lambda_c \rightarrow p\pi\pi$ (PRL117 232002 (2016))
- $\Lambda_c \rightarrow nK^0_S\pi^+$ (PRL 118, 112001 (2017))
- $\Lambda_c \rightarrow \Lambda \mu \nu$ (Phys. Lett. B 767, 42 (2017))
- $\Lambda_c \rightarrow p\eta$ e $\Lambda_c \rightarrow p\pi^0$ (PRD95, 111102(R) (2017))
- $\Lambda_c \rightarrow \Sigma^-\pi^+\pi^+$ and $\Lambda_c \rightarrow \Sigma^-\pi^+\pi^+\pi^0$ (PLB 772 (2017) 388-393)

Published measurements…

…discussed today

- $\Lambda_c \rightarrow \Lambda e \nu$ (PRL115, 221805 (2015))
- First Direct Measurement of Λ_c BF at threshold (PRL116 052001 (2016))
- $\Lambda_c \rightarrow pKK$ e $\Lambda_c \rightarrow p\pi\pi$ (PRL117 232002 (2016))
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- $\Lambda_c \rightarrow p\eta$ e $\Lambda_c \rightarrow p\pi^0$ (PRD95, 111102(R) (2017))
- $\Lambda_c \rightarrow \Sigma^-\pi^+\pi^+$ and $\Lambda_c \rightarrow \Sigma^-\pi^+\pi^+\pi^0$ (PLB 772 (2017) 388-393)
- Cross section at threshold (preliminary)

First direct measurements of Λ_c BF at threshold

- First absolute BF measurements of the golden mode, while improving the BF of other 11 Cabibbo Favored hadronic modes.

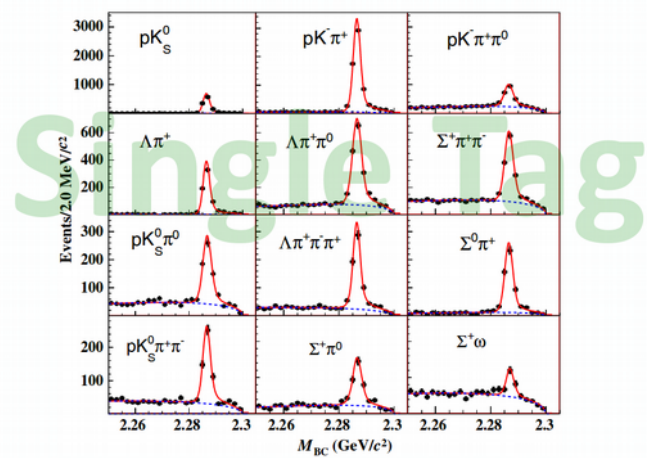
- BF measured with double tag technique (example):

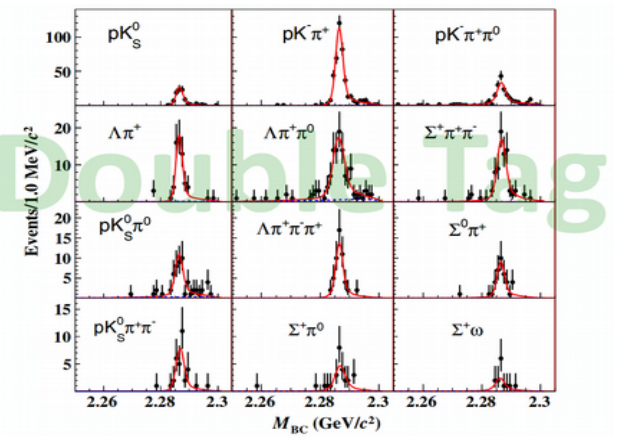
$$BF(\Lambda_c^+ \to pK^-\pi^+) =$$

$$N_{DT}/N_{ST} \times \varepsilon(\bar{\Lambda}_c^- \to \bar{\Lambda}\pi^-)/\varepsilon(\bar{\Lambda}_c^- \to \bar{\Lambda}\pi^- \,\&\&\, \Lambda_c^+ \to pK^-\pi^+)$$

  - Measurements are indipendent with respect to the number of Λ_c pairs produced
    - $N_{\Lambda c}$ will be a by-product using a simulatenous fit to all the final states

  - Systematic of the tag mode are canceled out in the ratio





PRL116 052001 (2016)

First direct measurements of Λ_c BF at threshold

With the Double Tag technique
very clean environment

Mode	This work (%)	PDG (%)	BELLE $\mathcal{B}$
pK_S^0	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S^0\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK_S^0\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	$4.53 \pm 0.23 \pm 0.30$	3.4 ± 1.0	
$\Lambda\pi^+$	$1.24 \pm 0.07 \pm 0.03$	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	$7.01 \pm 0.37 \pm 0.19$	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	$3.81 \pm 0.24 \pm 0.18$	2.6 ± 0.7	
$\Sigma^0\pi^+$	$1.27 \pm 0.08 \pm 0.03$	1.05 ± 0.28	
$\Sigma^+\pi^0$	$1.18 \pm 0.10 \pm 0.03$	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	$4.25 \pm 0.24 \pm 0.20$	3.6 ± 1.0	
$\Sigma^+\omega$	$1.56 \pm 0.20 \pm 0.07$	2.7 ± 1.0	

PRL116 052001 (2016)

1) $B(\Lambda_c \to pK^-p^+)$ consistent with PDG2014 within 2σ

- Same precision as BELLE
- Shall improve in the future with more data

2) Obtained the number of Λ_c pairs

- $N_{\Lambda c} = (105.9 \pm 4.8 \pm 0.5) \times 10^3$

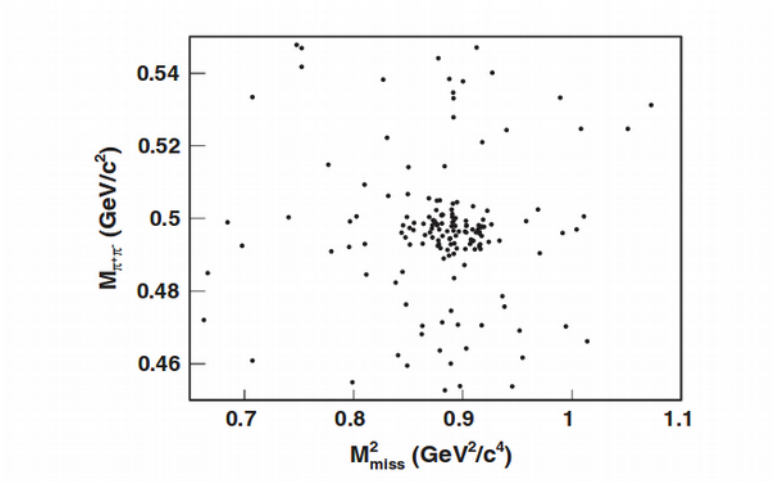
3) Improved meeasurements of other 11 CF channels

Observation of $\Lambda_c \to nK^0_s \pi^+$

PRL118,112001(2016)

First direct measurement a final state with neutron
Test if factorization scheme holds in charmed baryon decay (after it fails in charmed meson)

Double Tag analysis: neutron mass is reconstructed as missing mass

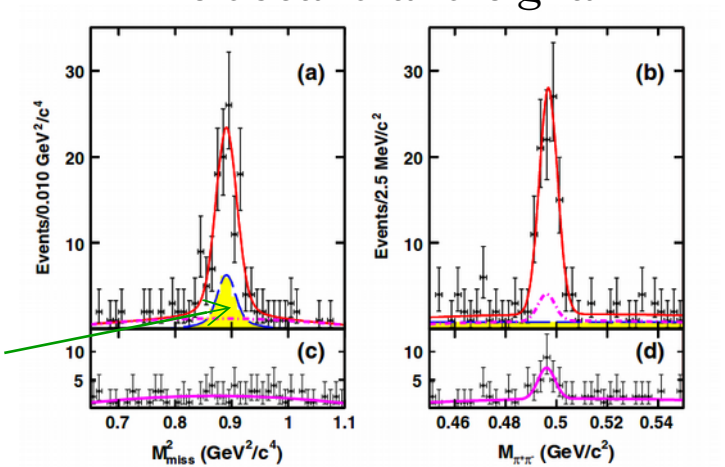


$$BF(\Lambda_c^+ \to nK_s^0\pi^+) = (1.82 \pm 0.23 \pm 0.11)\%$$

First observation!

Simultaneous 2D fit to sideband and signal

$\Sigma(n\pi)\pi\pi$



$$BF(\Lambda_c^+ \to nK^0\pi^+)/BF(\Lambda_c^+ \to pK^0\pi^0) = (0.97 \pm 0.16)$$
$$BF(\Lambda_c^+ \to nK_s^0\pi^+)/BF(\Lambda_c^+ \to pK^-\pi^+) = (0.63 \pm 0.09)$$

Test of the isospin relation:

$$\mathcal{A}(n\bar{K}^0\pi^+) + \mathcal{A}(pK^-\pi^+) + \sqrt{2}\mathcal{A}(p\bar{K}^0\pi^0) = 0.$$

$\Lambda_c \to \Sigma^-\pi^+\pi^+$ and $\Lambda_c \to \Sigma^-\pi^+\pi^+\pi^0$

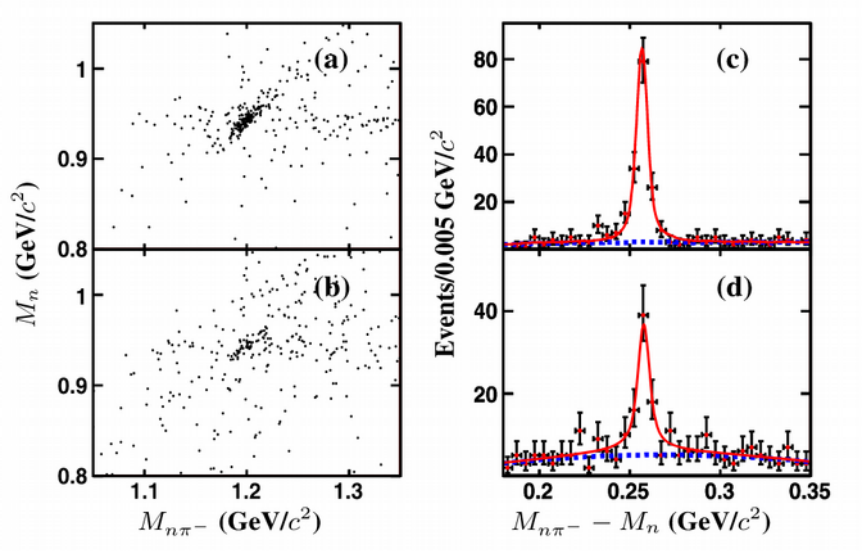
(PRD95, 111102(R) (2017))

First observation of the predicted large $\Lambda_c \to \Sigma^-\pi^+\pi^+\pi^0$ and first direct measurement of $\Lambda_c \to \Sigma^-\pi^+\pi^+$

Double Tag analysis in which the neutron is reconstructed as missing mass using:

$$M_n = \sqrt{(E_{\rm beam} - E_{\pi^+\pi^+\pi^-(\pi^0)})^2 - |\vec{p}_{\Lambda_c^+} - \vec{p}_{\pi^+\pi^+\pi^-(\pi^0)}|^2}$$

$$M_{n\pi^-} = \sqrt{(E_{\rm beam} - E_{\pi^+\pi^+(\pi^0)})^2 - |\vec{p}_{\Lambda_c^+} - \vec{p}_{\pi^+\pi^+(\pi^0)}|^2}$$



Number of signal is extracted from ($M_{n\pi} - M_n$) distribution since the two variables are highly correlated

$$BF(\Lambda_c^+ \to \Sigma^-\pi^+\pi^+) = (1.81 \pm 0.17)\%$$

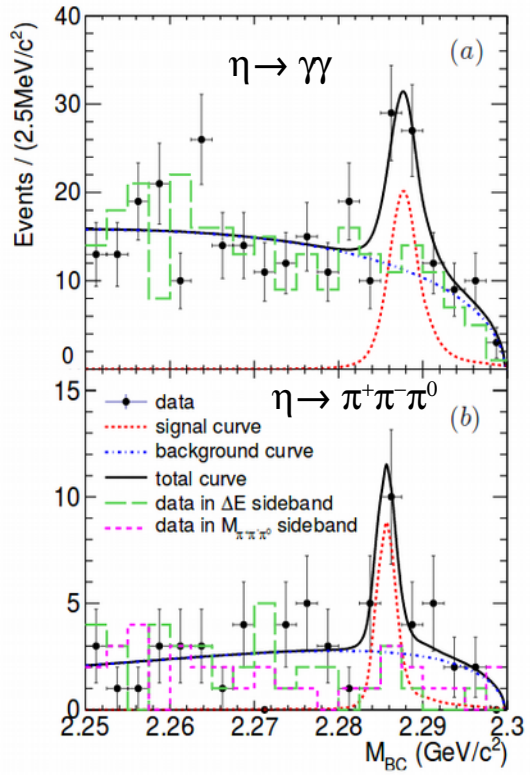
$$BF(\Lambda_c^+ \to \Sigma^-\pi^+\pi^+\pi^0) = (2.11 \pm 0.33)\%$$

PLB 772 (2017) 388-393

$\Lambda_c \to p\eta$ and $p\pi^0$

Search and study of SCS decay of Λ_c: ST Analyses

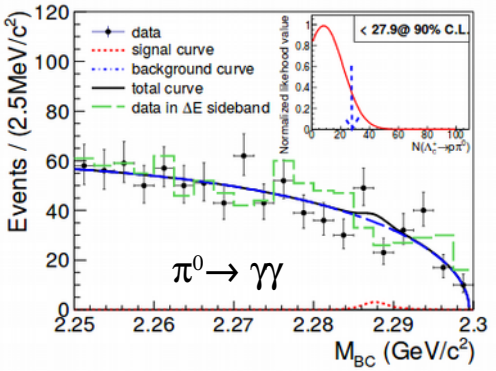
First evidence of $\Lambda_c \to p\eta$: 4.2σ



$$BF(\Lambda_c^+ \to p\eta) = (1.24 \pm 0.28 \pm 0.10) \times 10^{-3}$$

$$BF(\Lambda_c \to p\pi^0) < 2.7 \times 10^{-4} \,@\, 90\%\,\text{C.L.}$$

Upper Limit of $\Lambda_c \to p\pi^0$



	$\Lambda_c^+ \to p\eta$	$\Lambda_c^+ \to p\pi^0$	$\frac{\mathcal{B}_{\Lambda_c^+ \to p\pi^0}}{\mathcal{B}_{\Lambda_c^+ \to p\eta}}$
BESIII	1.24 ± 0.29	< 0.27	< 0.24
Sharma *et al* [3]	0.2[a](1.7[b])	0.2	1.0[a](0.1[b])
Uppal *et al* [4]	0.3	0.1-0.2	0.3-0.7
S. L. Chen *et al* [12]	...	0.11-0.36[c]	...
Cai-Dian Lü *et al* [13]	...	0.45	...

Discriminate between different theoritical models: BESIII tends to the one of Sharma et al assuming negative sign p-wave of $\Lambda_c \to \Xi^0 K^+$

K. K. Sharma, R. C. Verma, Phys. Rev. D 55, 7067 (1997)

Λ_c cross sections near threshold

(preliminary)

One Photon Exchange (OPEX) prediction for baryon-antybarion production at threshold

$$\sigma_{B\bar{B}}(q) = \frac{4\pi\alpha^2 C\beta}{3q^2}[|G_M(q)|^2 + \frac{1}{2\tau}|G_E(q)|^2]$$

For pointlike baryon Coulomb factor is described by $C = \varepsilon R$, with $\varepsilon = \frac{\pi\alpha}{\beta}$ and $R = \frac{\sqrt{1-\beta^2}}{1-e^{-\pi\alpha/\beta}}$ → σ(@threshold) ≠ 0

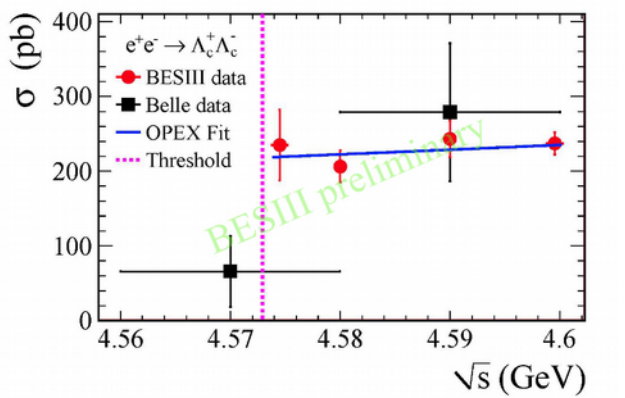
Moreover:

BESIII has recently shown an enhancement at $\Lambda\bar{\Lambda}$ threshold

BaBar data shows the pp at threshold is flat [1]

BELLE has scan the $\Lambda_c\Lambda_c$ threshold with ISR techniques [2]

Measure the cross section close to threshold to address Coulomb factor



[1] PRD 87, 092005 (2013), [2] PRL 101, 172001 (2008)

Future plans

Amazing results with limited statistics

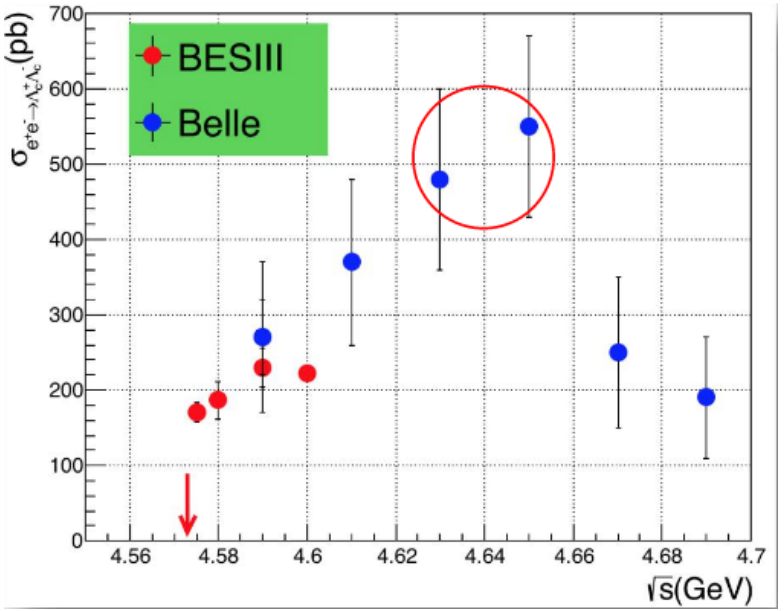
In the future we plan to collect 3/fb at 4.6 GeV (or higher, based on the machines upgrade)

Data taking would cost ~ 5-6 months

Luminosity (4.64 GeV) can be up to 15 times more the present one, if BELLE measurements hold

Possibility to precision similar to the one of charmed mesons

Beyond Λ_c physics, with high statistics sample at higher energy we can also address Y(4660), out of reach at the moment



Outlook

- BESIII program started in 2014 and has already accomplished very important results
  - Direct BF of 12 CF decay measurement
  - Improving precision of the golden channels
  - First observation of final states involving neutrons
  - $\Lambda_c \to \Lambda l\nu$ to test lepton flavor
  - Many others analysis are on-going and published soon ($\Lambda_c \to \Lambda X$, $\Lambda_c \to \Xi^{(*)}K^-$, Λ_c inclusive semileptonic, $\Lambda_c \to p\phi\pi^0$ among the others)

- In the near future the precision can be increased with even more data
  - To reach the level of charmed meson, so stay tuned!

	golden mode	δB/B	SL	δB/B
D0	B(KΠ)=(3.88±0.05)%	1.3%	B(Kev)=(3.55±0.05)%	1.4%
D+	B(KΠΠ)=(9.13±0.19)%	2.1%	B(K0ev)=(8.83±0.22)%	2.5%
Ds	B(KKΠ)=(5.39±0.21)%	3.9%	B(φev)=(2.49±0.14)%	5.6%
Λc	B(pKΠ) =(6.8±0.36)% (BELLE) =(5.84±0.35)% (BESIII)	5.3% 6.0%	B(Λev) =(3.63±0.43)% (BESIII)	12%

THANKS

谢谢！

Additional Material

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

For a total of 14415 ±159 in 11 ST mode

Factorization in $\Lambda_c \to N\bar{K}\pi$

In the three body decay, the total decay amplitude can be decomposed into two isospin amplitude of the NK system, an isosinglet $I^{(0)}$ and a isotriplet $I^{(1)}$.

In the factorization limit, the color-allowed tree diagram in which the π^+ is emitted and the NK is a isosinglet, dominates $I^{(0)}$, and $I^{(1)}$ is expected to be small.

Combined with the isospin partners, it is possible to determine the magnitudes of the two isospin amplitudes and and their phase difference. Important to address features of the final state interactions.

According to [5], based on the ratios, it is possible to extract the phase:

$$cos\delta = -0.24 \pm 0.08$$

And the ratio of the amplitudes

$$|I^{(1)}|/|I^{(0)}| = 1.14 \pm 0.11$$

Factorization scheme seems to be spoiled also in charmed barions

[5] C.-D. Lü, W. Wang, and F.-S. Yu, Phys. Rev. D 93, 056008 (2016)