Charmed Baryon Λ_c Decays at BESIII

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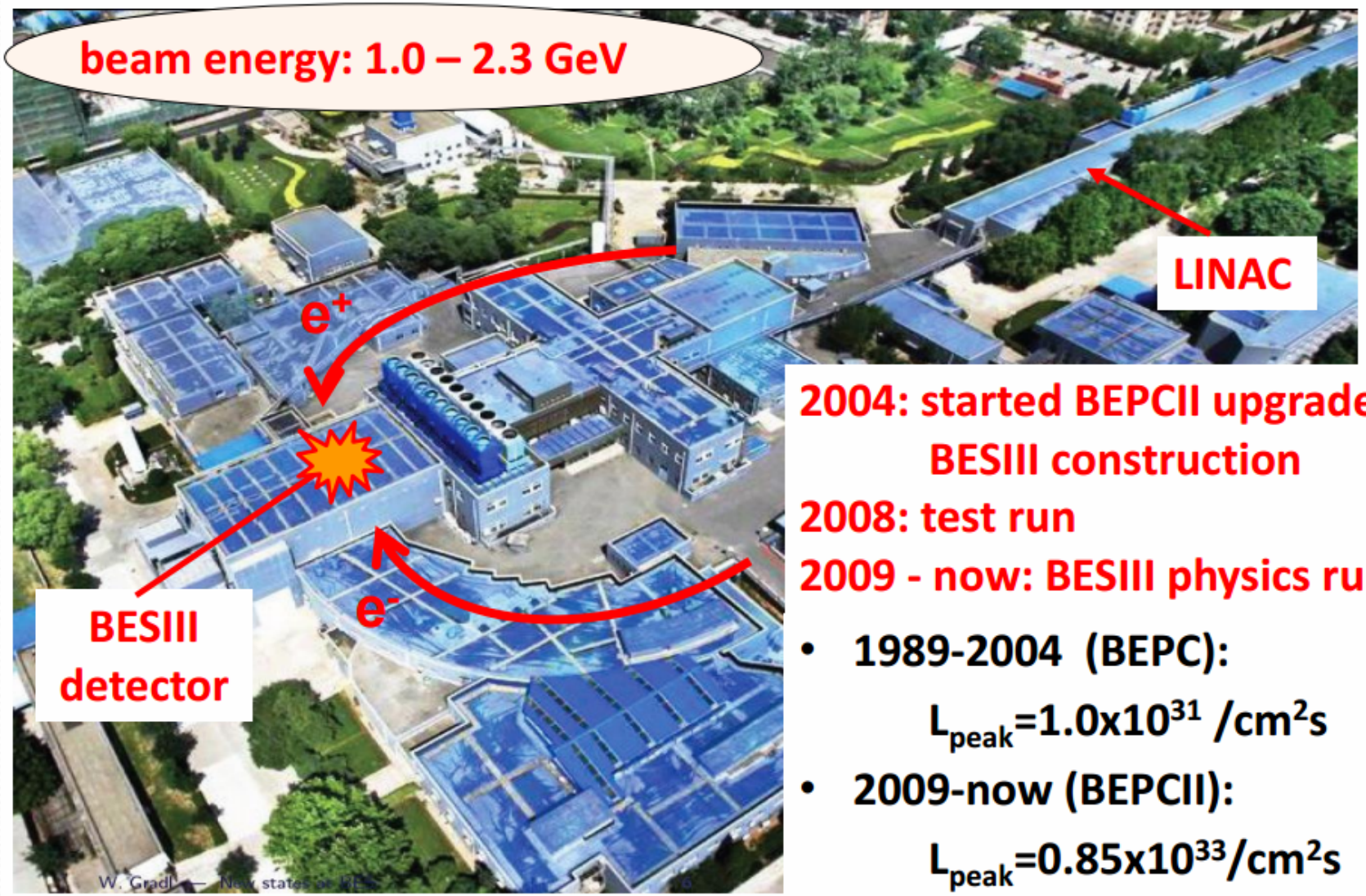
Outline

- **Introduction**
- **Λ_C^+ hadronic and semileptonic decays(@4.6GeV)**
  - Branching fraction of hadronic modes
  - Branching fraction of semileptonic decay:$\Lambda^+_C \rightarrow \Lambda e^+ \nu_e$
- **Summary**

Beijing Electron Positron Collider



2004: started BEPCII upgrade,
BESIII construction

2008: test run

2009 - now: BESIII physics run

- 1989-2004 (BEPC):

  $L_{peak}=1.0\times10^{31}$ /cm^{2}s
- 2009-now (BEPCII):

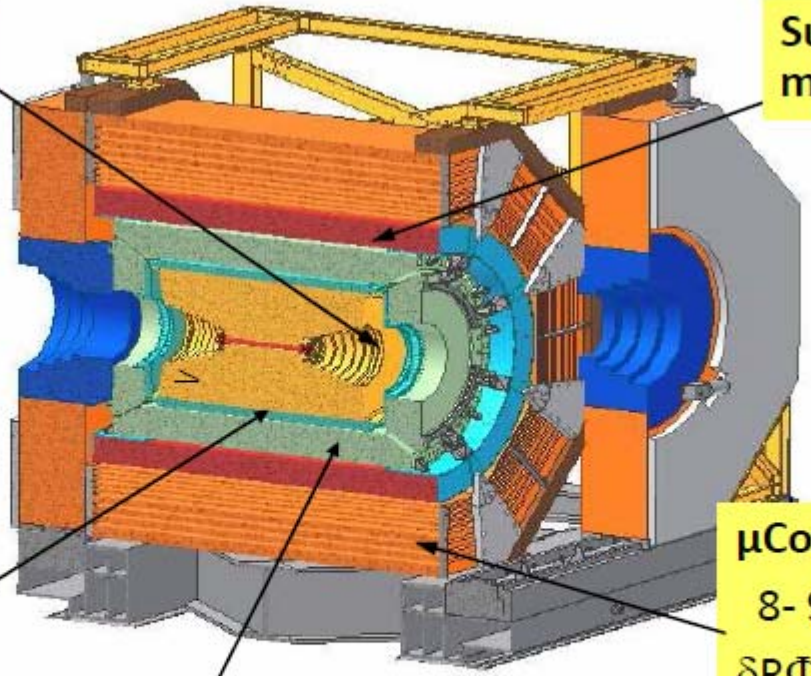
  $L_{peak}=0.85\times10^{33}$/cm^{2}s

The BESIII detector

Drift Chamber (MDC)

$\sigma P/P\ (^0/_0) = 0.5\%(1GeV)$

$\sigma_{dE/dx}\ (^0/_0) = 6\%$



Super-conducting magnet (1.0 tesla)

Time Of Flight (TOF)

σ_T: 90 ps Barrel

110 ps endcap

μCounter

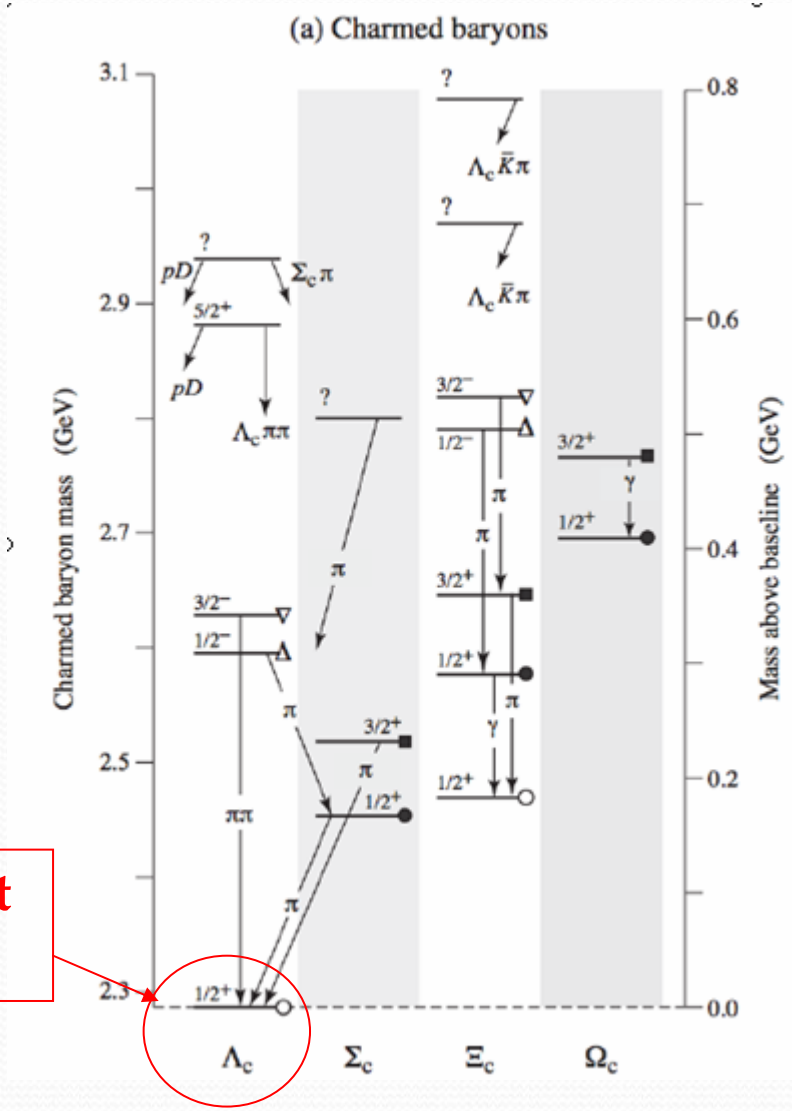
8- 9 layers RPC

$\delta R\Phi$=1.4 cm~1.7 cm

EMC: $\sigma E/\sqrt{E}(^0/_0) = 2.5\ \%\ (1\ GeV)$

(CsI) $\sigma_{z,\phi}(cm) = 0.5 - 0.7\ cm/\sqrt{E}$

Charmed baryon



- Λ^+_C is the lightest charmed baryon

BESIII data taken

- In 2014, BESIII took data above Λ^+_C pair threshold and run machine @4.6GeV with excellent performance! This is a marvelous achivement of BES!

available data set at BESIII

Energy(GeV)	lum.(1/pb)
4.575	~48
4.580	~8.5
4.590	~8.1
4.600	~567

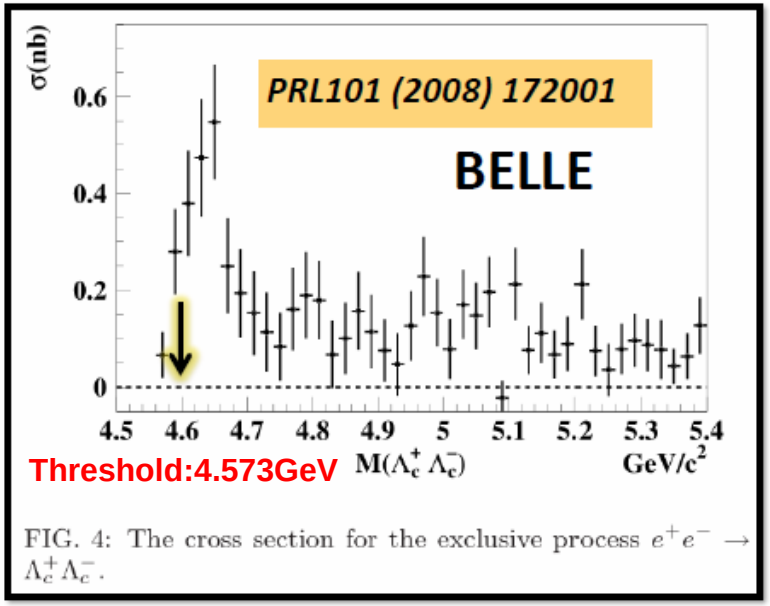
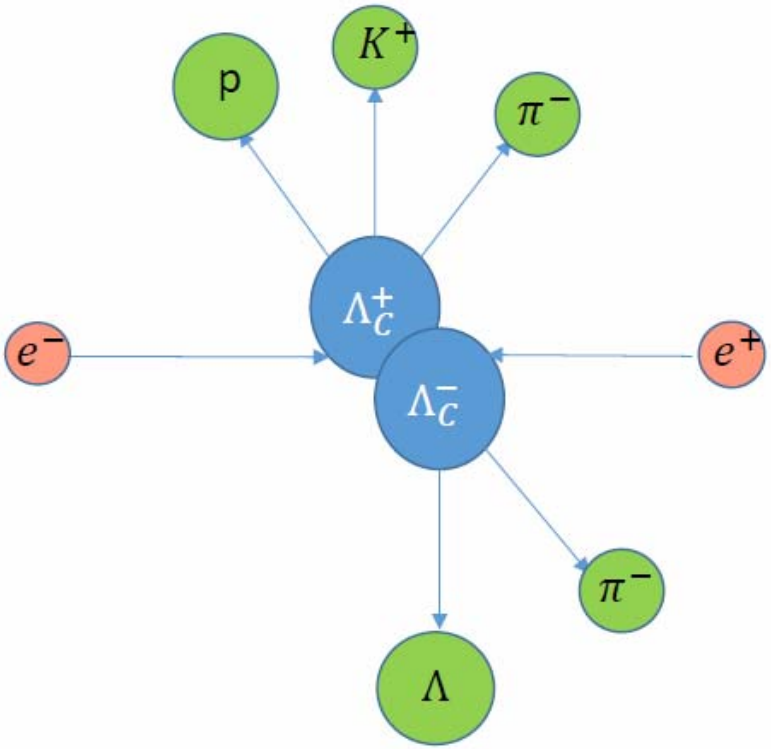


FIG. 4: The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

First time to systematically study charmed baryon at threshold!

Λ^+_c selection

mode
$\Lambda_c \to pK_s$
$\Lambda_c \to pk^-\pi^+$
$\Lambda_c \to pK_S\pi^0$
$\Lambda_c \to pK_S\pi^+\pi^-$
$\Lambda_c \to pk^-\pi^+\pi^0$
$\Lambda_c \to \Lambda\pi^+$
$\Lambda_c \to \Lambda\pi^+\pi^0$
$\Lambda_c \to \Lambda\pi^+\pi^-\pi^+$
$\Lambda_c \to \Sigma^0\pi^+$
$\Lambda_c \to \Sigma^+\pi^0$
$\Lambda_c \to \Sigma^+\pi^+\pi^-$
$\Lambda_c \to \Sigma^+\omega$



12 modes used in reconstruction of Λ_C covers ~1/3 of the total decays.

Constructing particles from final state particles:

- $K_S \to \pi^+\pi^-$
- $\pi^0 \to \gamma\gamma$
- $\Lambda \to p\pi^-$
- $\Sigma^0 \to \Lambda\gamma$
- $\Sigma^+ \to p\pi^0$
- $\omega \to \pi^+\pi^-\pi^0$

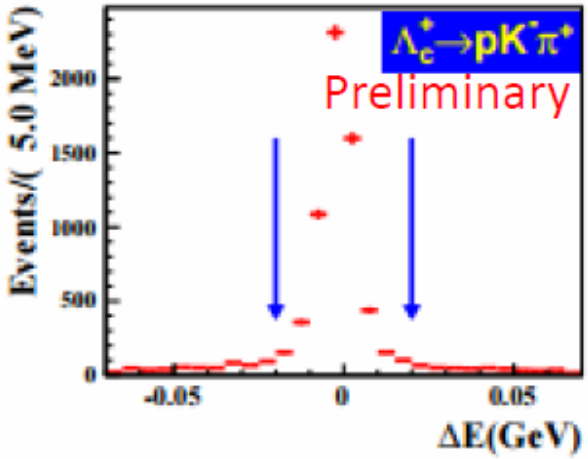
Tagging method

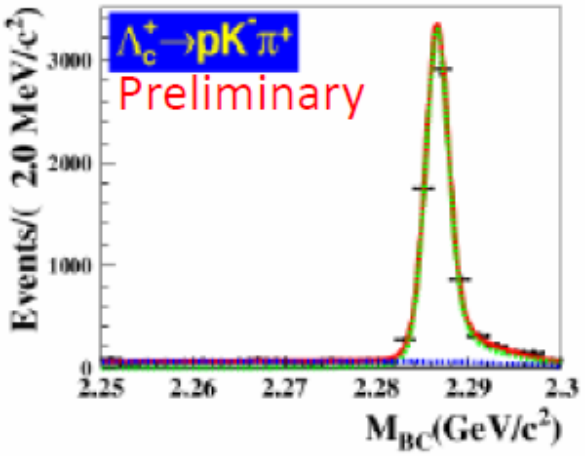
Single Tag (ST) $\Lambda_c^{\pm} \to i$

Reconstruct candidate particles for $\Lambda_c^{\pm}$ decay.

$$\Delta E = E_{\Lambda_c Rec} - E_{Beam}$$

$$M_{bc} = \sqrt{E_{beam}^2 - |\vec{P}_{\Lambda_c Rec}|^2}$$





Double Tag (DT) $\Lambda_c^+ \to i, \Lambda_c^- \to j$

Reconstruct candidates particles for both Λ_c^+ and Λ_c^- decays.

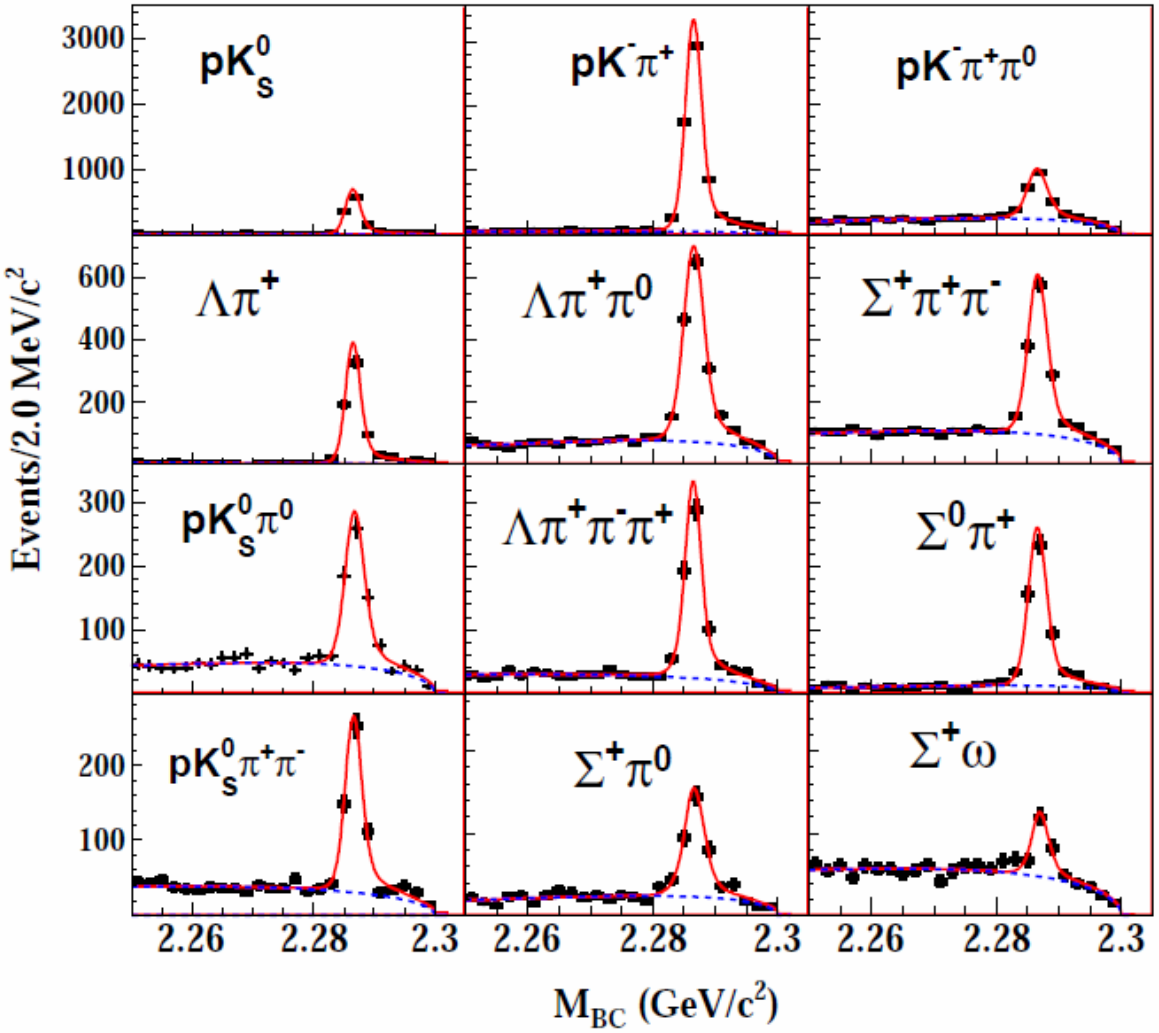
- Used to cancel out model dependence
- Background reduced
- Statistically suffer

Absolute BFs of hadronic modes

- Absolute BFs of Λ^+_C decays are not well determined.
- Belle result: $\boldsymbol{B}(\Lambda^+_C \rightarrow pK^-\pi^+) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$ **PRL113(2014) 042002**
- Most Cabibbo-favored hadronic BFs still have poor accuracy
- Using threshold pair-productions via e+e- annihilation: *the most simple and straightforward*

ST yields

BESIII *preliminary*

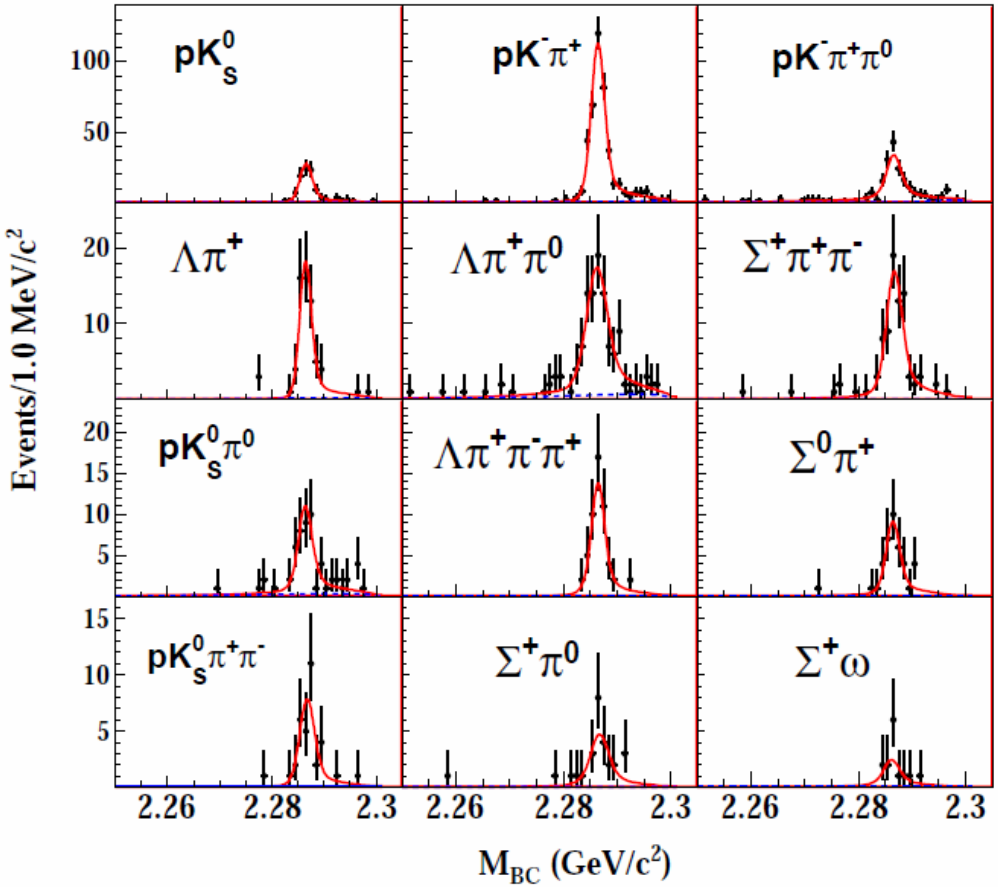


Mode	N_j^{ST}
pK_S^0	1243 ± 37
$pK^-\pi^+$	6308 ± 88
$pK_S^0\pi^0$	558 ± 33
$pK_S^0\pi^+\pi^-$	485 ± 29
$pK^-\pi^+\pi^0$	1849 ± 71
$\Lambda\pi^+$	706 ± 27
$\Lambda\pi^+\pi^0$	1497 ± 52
$\Lambda\pi^+\pi^-\pi^+$	609 ± 31
$\Sigma^0\pi^+$	522 ± 27
$\Sigma^+\pi^0$	309 ± 24
$\Sigma^+\pi^+\pi^-$	1156 ± 49
$\Sigma^+\omega$	157 ± 22

ST sum:~15K

DT yields

BESIII *preliminary*



Mode	$N^{\rm DT}_{i-}$
pK^0_S	97 ± 10
$pK^-\pi^+$	420 ± 22
$pK^0_S\pi^0$	47 ± 8
$pK^0_S\pi^+\pi^-$	34 ± 6
$pK^-\pi^+\pi^0$	176 ± 14
$\Lambda\pi^+$	60 ± 8
$\Lambda\pi^+\pi^0$	101 ± 13
$\Lambda\pi^+\pi^-\pi^+$	53 ± 7
$\Sigma^0\pi^+$	38 ± 6
$\Sigma^+\pi^0$	25 ± 5
$\Sigma^+\pi^+\pi^-$	80 ± 9
$\Sigma^+\omega$	13 ± 3

$$N^{DT}_{-j} = \sum_{i^+\neq j} N^{DT}_{i^+j^-} + \sum_{i^-\neq j} N^{DT}_{i^-j^+} + N^{DT}_{jj}$$

Where, $N^{\rm DT}_{i+j-}$ is the DT yield with $\Lambda_c^+ \to$ i and $\Lambda_c^- \to$ j.

Hadronic BFs results

- We perform a simultaneousfit to all tag modes, taking into account the correlations.

BESIII *preliminary*

Decay modes	global fit $\mathcal{B}$	PDG $\mathcal{B}$ [1]	Belle $\mathcal{B}$ [6]
pK_S	$1.52 \pm 0.08 \pm 0.03$	1.15 ± 0.30	
$pK^-\pi^+$	$5.84 \pm 0.27 \pm 0.23$	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S\pi^0$	$1.87 \pm 0.13 \pm 0.05$	1.65 ± 0.50	
$pK_S\pi^+\pi^-$	$1.53 \pm 0.11 \pm 0.09$	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	

stat. and sys. err

- ✓ **$\mathcal{B}(pK^-\pi^+)$: BESIII precision comparable with Belle's result**
- ✓ **BESIII rate $\mathcal{B}(pK^-\pi^+)$ is smaller**
- ✓ **Improved precisions of the other 11 modes significantly**

Measurement of the BF of $\Lambda^+_c \rightarrow \Lambda e^+ \nu_e$

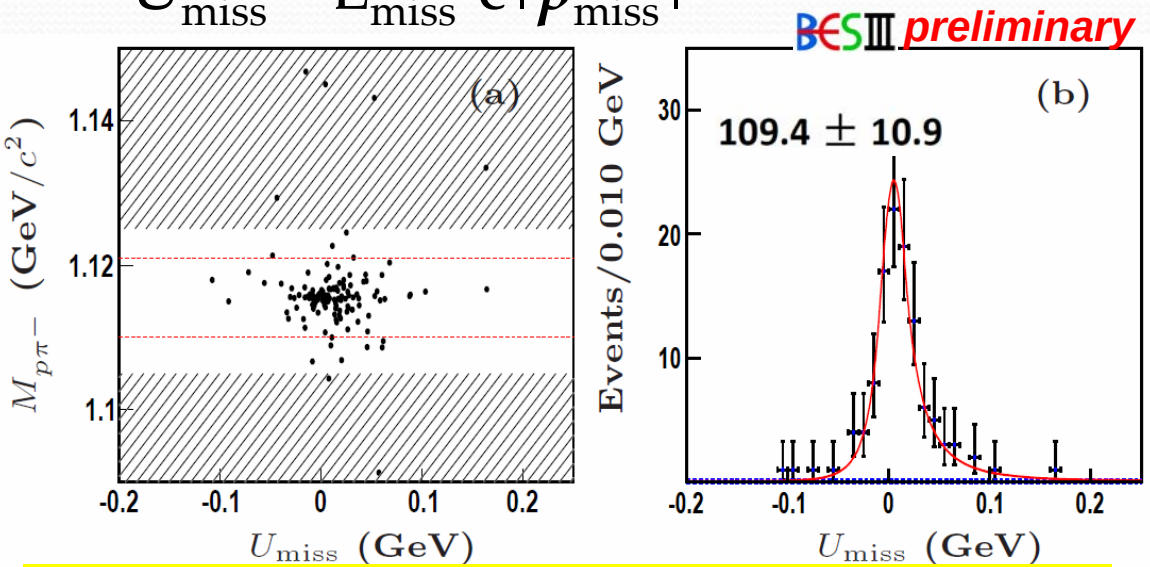
- $\Lambda^+_C \rightarrow \Lambda e^+ \nu_e$ is a $c \rightarrow s l^+ \nu_l$ dominated progress, provide important information for
  - testing the theoretical predication for $\boldsymbol{B}(\Lambda^+_C \rightarrow \Lambda e^+ \nu_e)$
  - calibrating the LQCD calculations
  - Addition information for determining CKM elements

- No direct absolute measurement:
  - $\boldsymbol{B}(\Lambda^+_C \rightarrow \Lambda e^+ \nu_e) = (2.1 \pm 0.6)\%$ (PDG2014) ,scaling to $(2.9 \pm .05)\%$based on Belle's $\boldsymbol{B}(pK^-\pi^+)$

- Theoretical predications for BF of $\boldsymbol{B}(\Lambda^+_C \rightarrow \Lambda e^+ \nu_e)$ range from 1.4%to 9.2%.

Determine the SL events

- 11 ST modes are used(except $\Sigma^+\omega$) to tag $N^{tot}_{\Lambda_C^-} = 14415 \pm 159$
- Require ΔE and M_{BC} signal region, reconstruct Λ and e^+ to obtain:
  - $U_{miss} = E_{miss} - c|\vec{p}_{miss}|$



subtraction of backgrounds:

- non-ST events: negligible
- Λ sidebands: 1.4 ± 0.8
- $\Lambda\mu^+\nu + \Lambda\pi^+\pi^0 + \Lambda\pi^+ = 4.5 \pm 0.5$

➔ **signal yields: 103.5 ± 10.9**

$$\boldsymbol{B}(\Lambda^+_C \rightarrow \Lambda e^+ \nu_e) = (3.63 \pm 0.38 \pm 0.20)\%$$

- Statistics limited measurement:sys.err smaller than stat. err
- Best precision to date:twofold improvement

Summary

- BESIII strated study of Λ^+_C decays using the world largest data at $\Lambda^-_C\Lambda^+_C$ pair threshold(4.6GeV)
- BESIII got comparable result of $\boldsymbol{B}(pK^-\pi^+)$ with Belle and improved precisions of other 11 Cabbibo-favored decays significantly.
- BESIII had a direct measurement of $\boldsymbol{B}(\Lambda^+_C \rightarrow \Lambda e^+\nu_e)$ firstly and twofold improved the precision.
- Many new exciting results are on their way!

Thank you!