Recent charmed baryon results at BESIII

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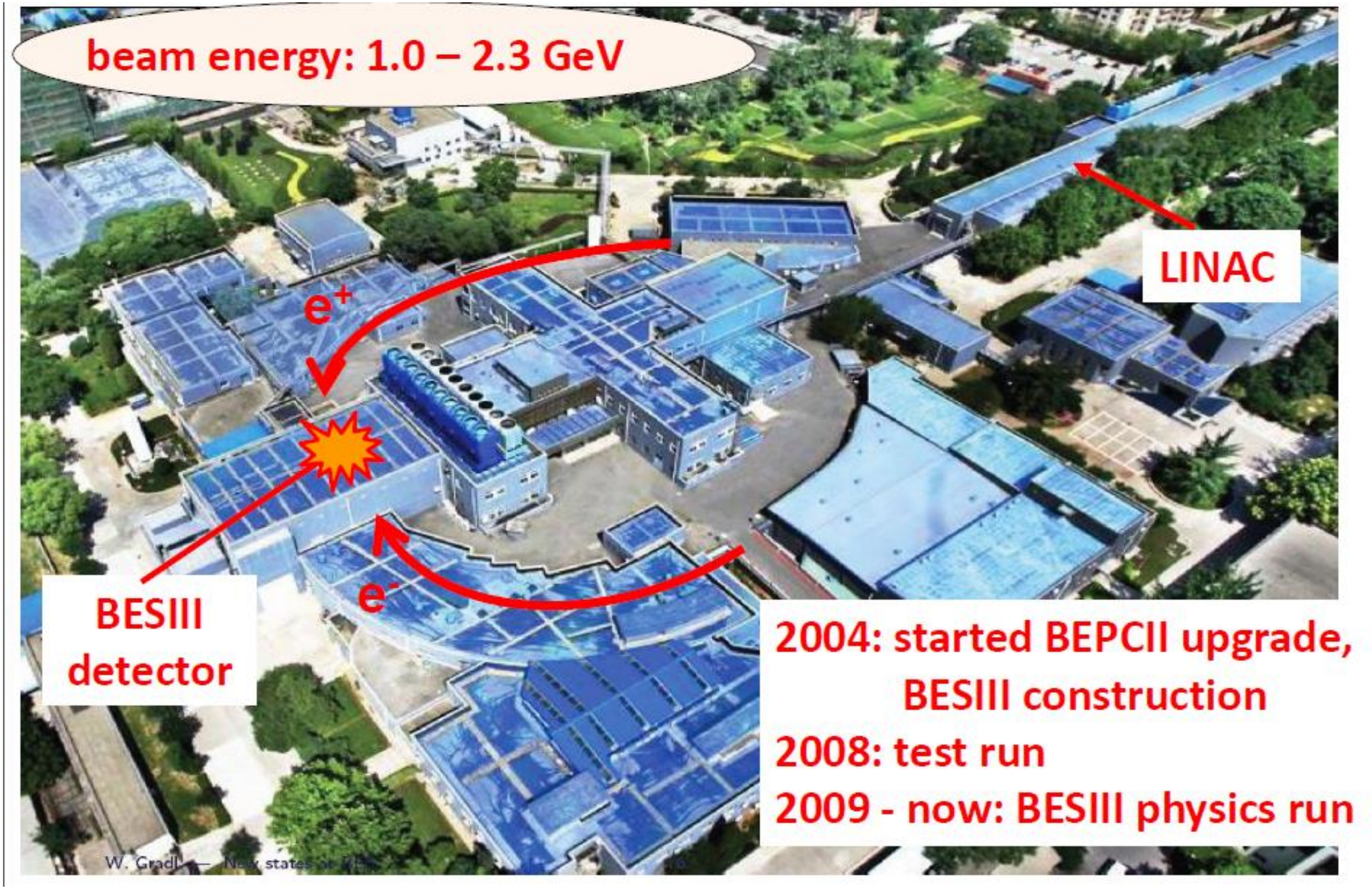
Outline

- **The BESIII experiment**
- **Λ_c^+ decays at threshold**
  - Λ_c^+ hadronic decays
  - Λ_c^+ semi-leptonic decays
- **Summary**

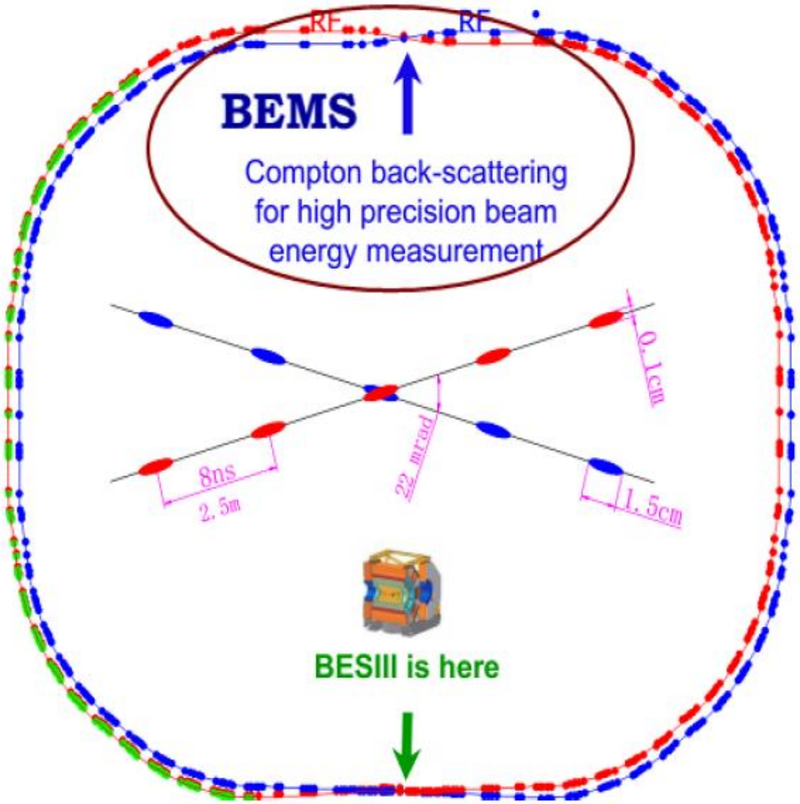
Beijing Electron Positron Collider (BEPCII)

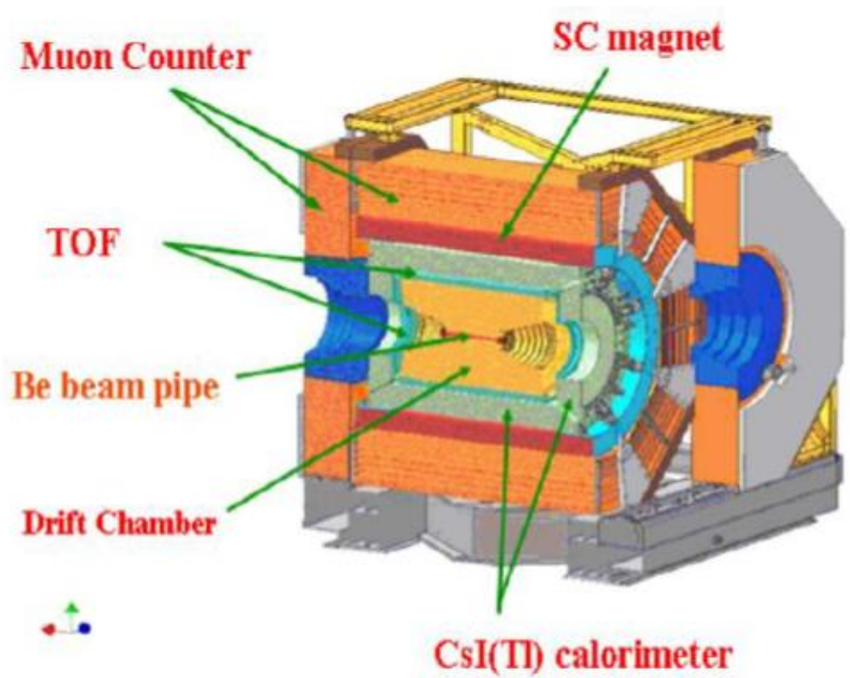


The BESIII Detector @ BEPCII

Peak Luminosity:
$0.85 \times 10^{33} cm^{-2} s^{-1}$ at $\psi(3770)$ in 2014

Excellent tracking:
$\delta p/p = 0.5\%$@1GeV
dE/dx=6%



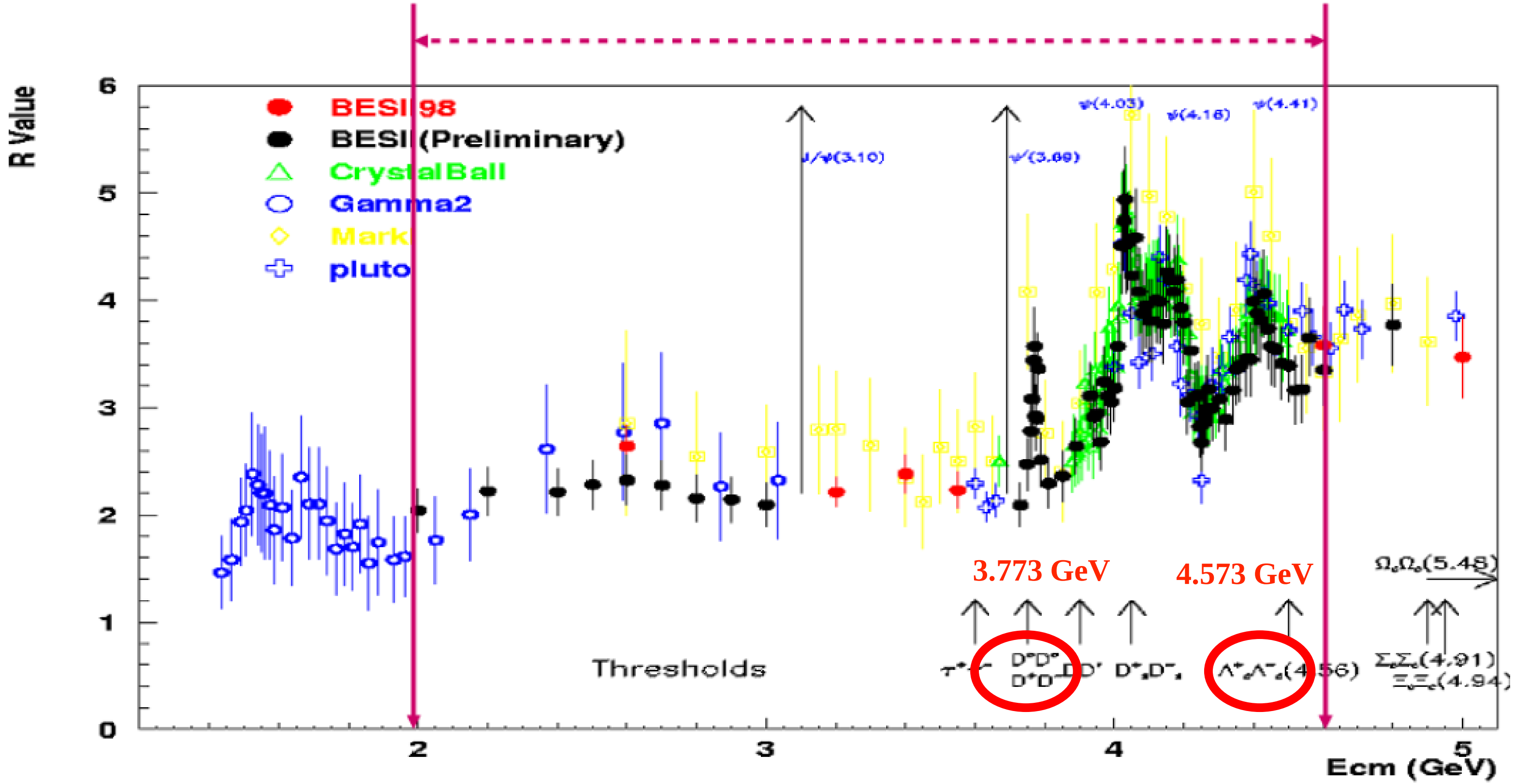


Time resolution:
70ps@BTOF
100ps@ETOF

Shower reconstruction:
$\delta E/E = 2.5\%$@1GeV

Energy range @BEPCII

2 ~ 4.6 GeV



- Rich of resonances: charmonia and charmed hadrons.
- Threshold characteristic(pairs of τ, D, D_s, Λ_c ...).
- Transition between smooth and resonances, perturbative and non-perturbative QCD.

New data taken for Λ_c^+ analysis

In 2014, BESIII took data above Λ_c pair threshold and run machine at 4.6GeV with excellent performance!

available data set for Λ_c^+ study

Energy(GeV)	lum.(pb^{-1})
4.575	~48
4.580	~8.5
4.590	~8.1
4.600	~567

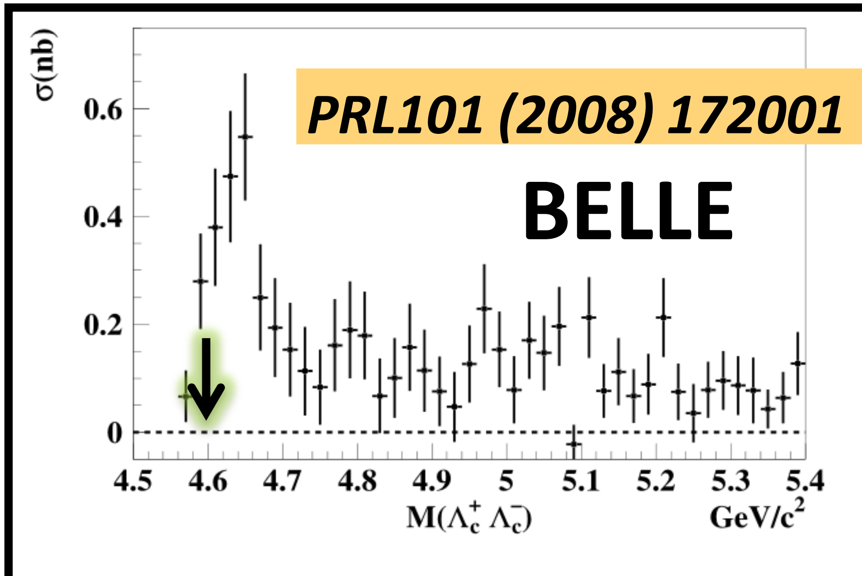


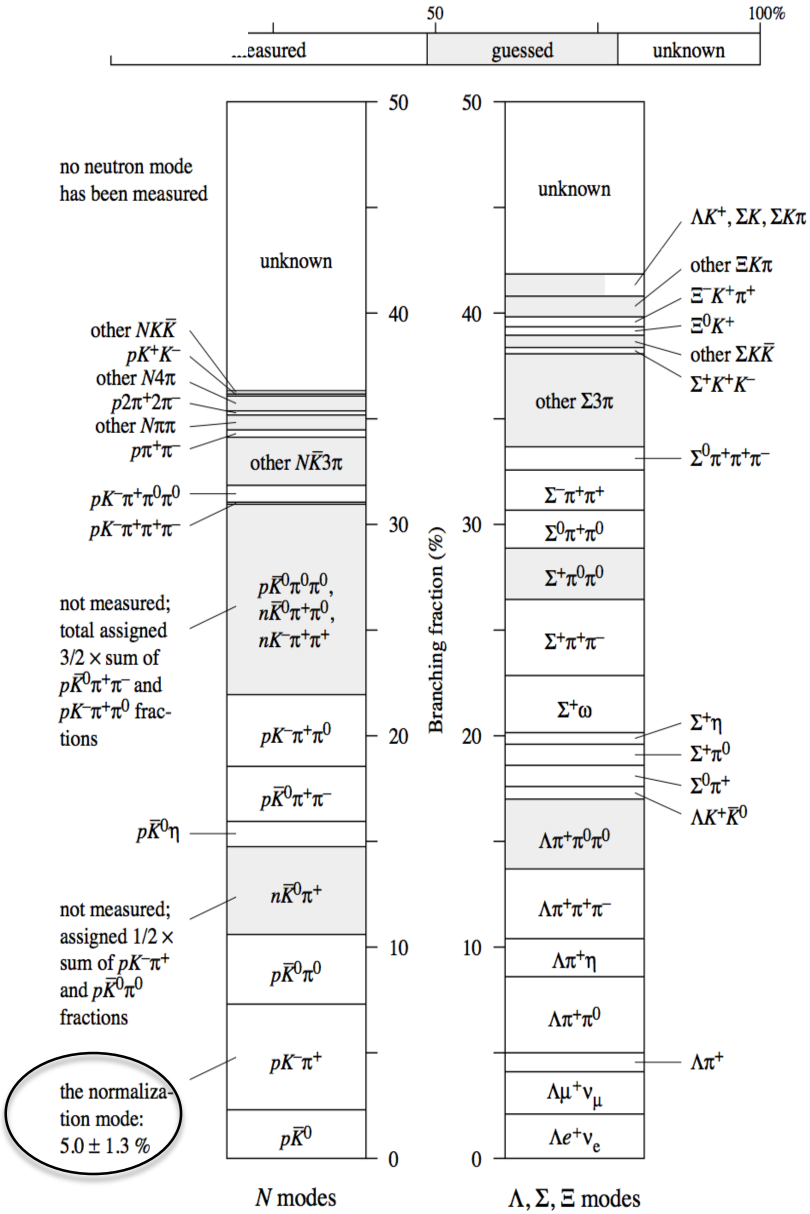
FIG. 4: The cross section for the exclusive process $e^+e^- \to \Lambda_c^+\Lambda_c^-$.

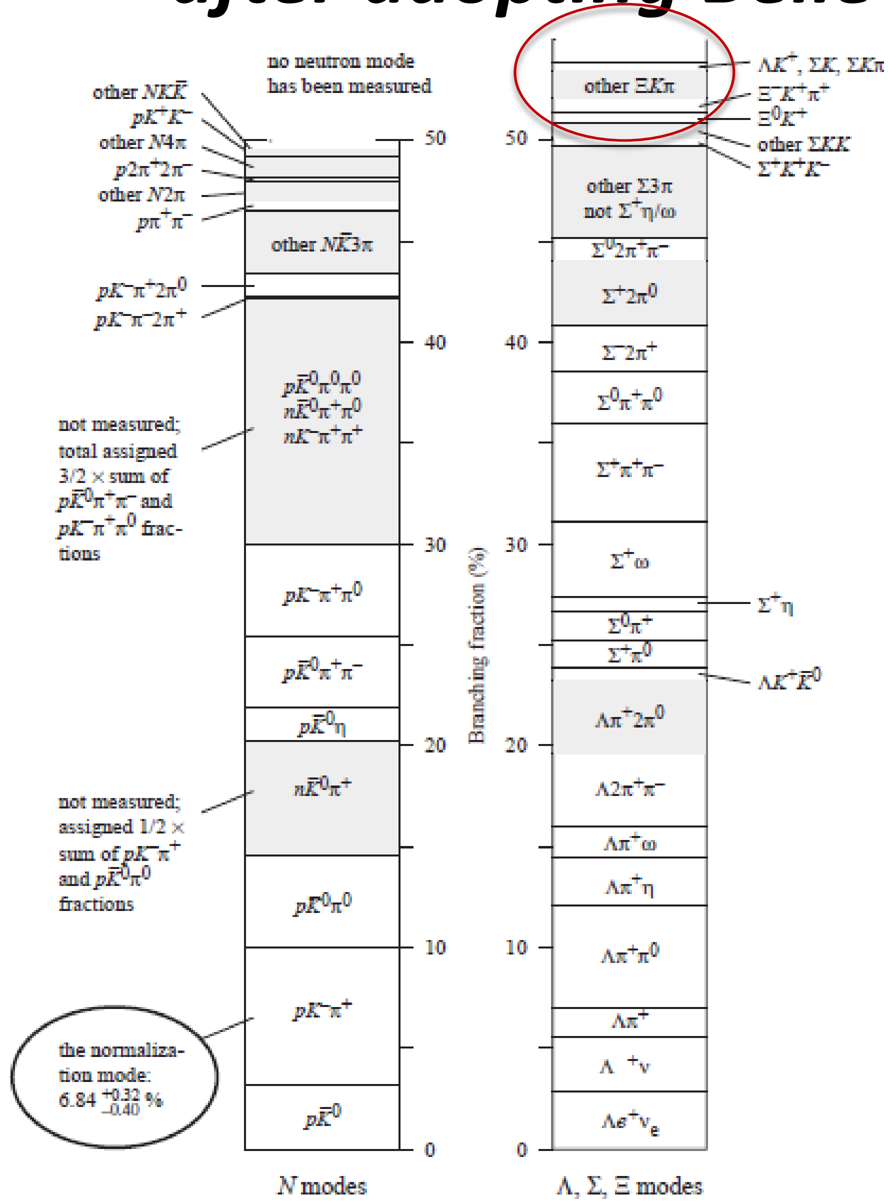
First time to systematically study charmed baryon at threshold!

Absolute BF of Λ_c^+ hadronic decays

- **Λ_c^+ decay rates are still not well determined**
  - BFs of most decay modes (~85%) are measured relative to $\Lambda_c^+ \to pK^-\pi^+$
  - No completely model-independent measurements of the absolute BF of $\Lambda_c^+ \to pK^-\pi^+$ (from Argus and CLEO very old results)
    uncertainties of BFs are 25%~40% in PDG2014
- **Belle's first precision measurement:**
  $B(\Lambda_c^+ \to pK^-\pi^+) = (6.84 \pm 0.24^{+0.21}_{-0.27})\%$
  precision reaches to 4.7%
  Phys. Rev. Lett. 113, 042002 (2014)
- **Measurement using the threshold pair-productions via e^+e^- annihilations is unique:**
  - the most simple and straightforward
  - kinematics does not allow additional particle produced along with the $\Lambda_c^+\Lambda_c^-$ pair
  - **Absolute measurement:** fully reconstruct the pairs and take ratios of DT yields and ST yields to measure the BFs

after adopting Belle's

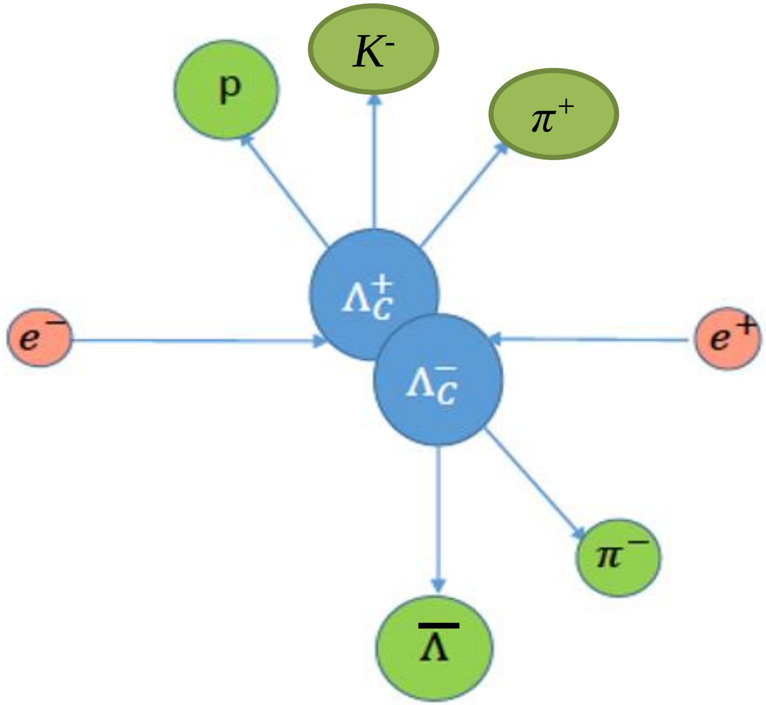




Detection of $\Lambda_c^+\Lambda_c^-$ pairs

12 modes

pK_S
$pK^-\pi^+$
$pK_S\pi^0$
$pK_S\pi^+\pi^-$
$pK^-\pi^+\pi^0$
$\Lambda\pi^+$
$\Lambda\pi^+\pi^0$
$\Lambda\pi^+\pi^-\pi^+$
$\Sigma^0\pi^+$
$\Sigma^+\pi^0$
$\Sigma^+\pi^+\pi^-$
$\Sigma^+\omega$



Constructing particles from final state particles:

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

- Use energy difference (ΔE) to improve S/B
- Extract signal yields in the beam-constrained mass (M_{BC})

$$\Delta E = E - E_{beam}$$

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

charge conjugate modes are implied in the following slides.

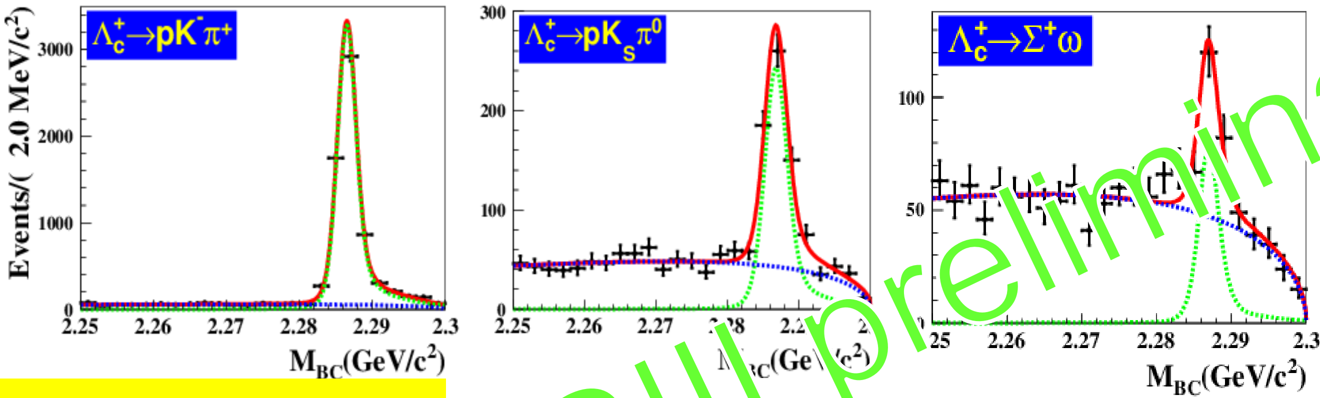
Estimation on the yields of the 12 modes

- ✓ ST yields $N_{i^+}^{ST} = N_{\Lambda_c^+\Lambda_c^-} \cdot \mathcal{B}_i \cdot \varepsilon_{i^+}^{ST}$
- ✓ DT yields $N_{i^+j^-}^{DT} = N_{\Lambda_c^+\Lambda_c^-} \cdot \mathcal{B}_i \cdot \mathcal{B}_j \cdot \varepsilon_{i^+j^-}^{DT}$

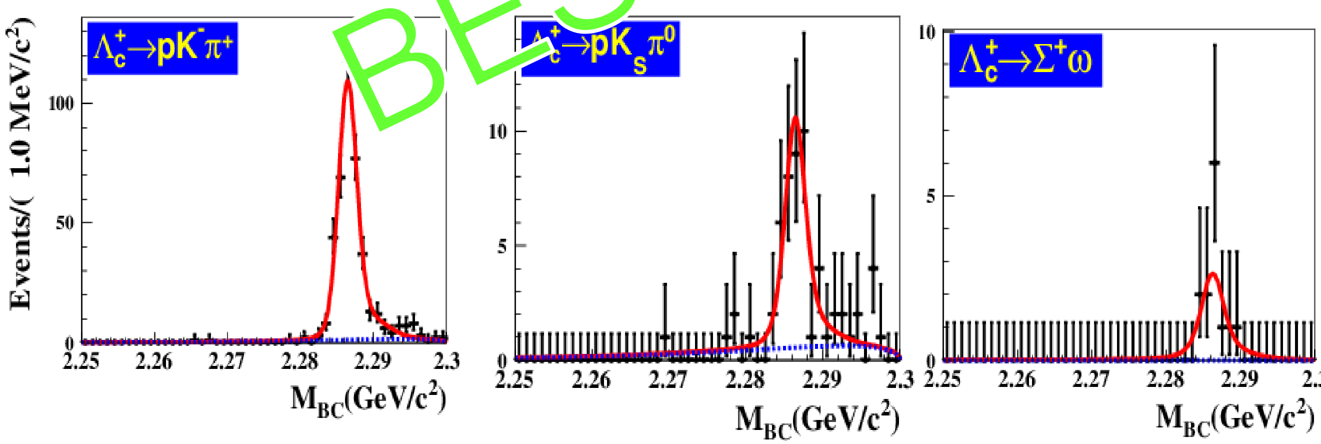
$$N_{-j}^{DT} = \sum_{i^+\neq j} N_{i^+j^-}^{DT} + \sum_{i^-\neq j} N_{i^-j^+}^{DT} + N_{jj}^{DT}$$

modes	N_i^{ST}	N_{-j}^{DT}
pK_S	1243 ± 37	89 ± 10
$pK^-\pi^+$	6308 ± 88	390 ± 21
$pK_S\pi^0$	558 ± 33	40 ± 7
$pK_S\pi^+\pi^-$	454 ± 28	29 ± 6
$pK^-\pi^+\pi^0$	1849 ± 71	148 ± 14
$\Lambda\pi^+$	706 ± 27	59 ± 8
$\Lambda\pi^+\pi^0$	1497 ± 52	89 ± 11
$\Lambda\pi^+\pi^-\pi^+$	609 ± 31	53 ± 7
$\Sigma^0\pi^+$	586 ± 32	39 ± 6
$\Sigma^+\pi^0$	271 ± 25	20 ± 5
$\Sigma^+\pi^+\pi^-$	836 ± 43	56 ± 8
$\Sigma^+\omega$	157 ± 22	13 ± 3

ST yields in data



DT yields in data



- **Dominated by $\Lambda_c^+\to pK^-\pi^+$**
- **Backgrounds are well controlled**

Hadronic branching fraction results

- **a least square global fitter: simultaneous fit to the all tag modes while constraining the total $\Lambda_c^{\pm}$ pair number, taking into account the correlations**

reference: Chinese Phys. C 37 , 106201 (2013)

BESIII prel.

Decay modes	global fit $\mathcal{B}$	PDG $\mathcal{B}$	Belle $\mathcal{B}$
pK_S	1.48 ± 0.08	1.15 ± 0.30	
$pK^-\pi^+$	5.77 ± 0.27	5.0 ± 1.3	$6.84 \pm 0.24^{+0.21}_{-0.27}$
$pK_S\pi^0$	1.77 ± 0.12	1.65 ± 0.50	
$pK_S\pi^+\pi^-$	1.43 ± 0.10	1.30 ± 0.35	
$pK^-\pi^+\pi^0$	4.25 ± 0.22	3.4 ± 1.0	
$\Lambda\pi^+$	1.20 ± 0.07	1.07 ± 0.28	
$\Lambda\pi^+\pi^0$	6.70 ± 0.35	3.6 ± 1.3	
$\Lambda\pi^+\pi^-\pi^+$	3.67 ± 0.23	2.6 ± 0.7	
$\Sigma^0\pi^+$	1.28 ± 0.08	1.05 ± 0.28	
$\Sigma^+\pi^0$	1.18 ± 0.11	1.00 ± 0.34	
$\Sigma^+\pi^+\pi^-$	3.58 ± 0.22	3.6 ± 1.0	
$\Sigma^+\omega$	1.47 ± 0.18	2.7 ± 1.0	

only stat. errors

- ✓ **$B(pK^-\pi^+)$: BESIII precision comparable with Belle's result**
- ✓ **BESIII rate $B(pK^-\pi^+)$ is smaller**
- ✓ **Precisions of the other 11 modes are also improved.**

Absolute Measurement decay rate of $\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e$

- **$B(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e)$ will provide important experimental information**
  - test the theoretical predications (ranges from 1.4% to 9.2%)
  - calibrate the LQCD calculations
  - determining CKM matrix elements.

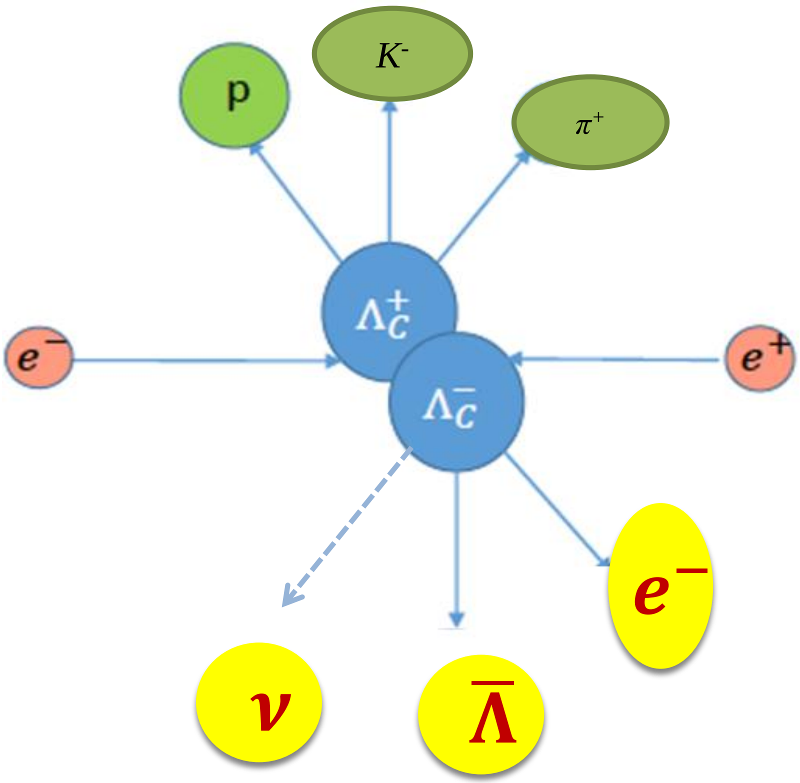
- **No direct absolute measurement for $B(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e)$ available.**
  - $B(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e) = (2.1 \pm 0.6)\%$ PDG2014
  - scaling to (2.9±0.5)%, when taking the Belle's $B(pK^- \pi^+)$

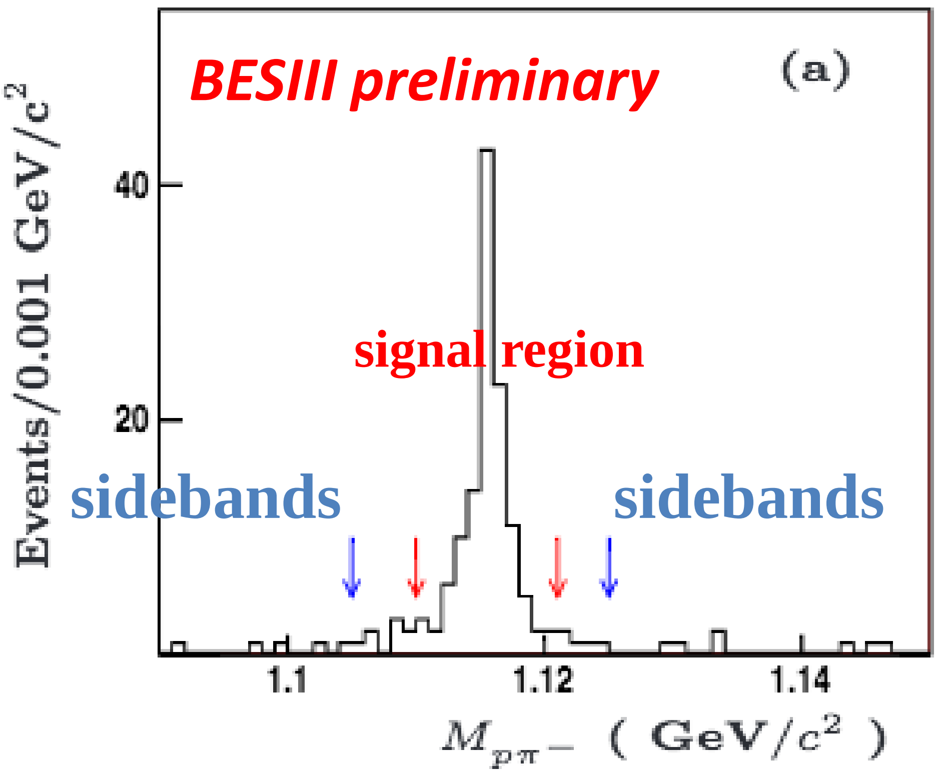
- **Production at threshold has advantages on this type of decays with missing particle!**
  - BESIII 567pb^{-1} data @4.6GeV will provide the measurement up to precision of $\delta B/B \sim 10\%$ by using DT method

Candidate events for $\Lambda_c^+ \to \Lambda e^+ \nu_e$

- **11 ST modes are used, except $\Sigma^+\omega$**
- **We detect p, π^-, e^+ among the remaining tracks form the ST Λ_c^-**
- **require p and π^- are from Λ**

clean Λ peak



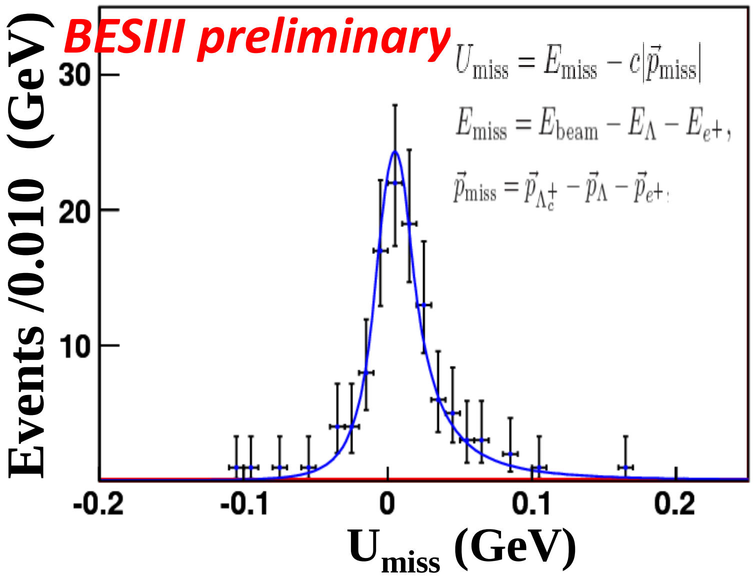


Semi-leptonic branching fraction results

✓ Fitting function:

- signals: Gaussian with two power law tails
- backgrounds: 1st order polynomial

567pb^{-1} **data** @ 4.6 GeV



subtraction of backgrounds:

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

➔ **signal yields: 103.5 ± 10.9**

BESIII Prel. : $B(\Lambda_c^+ \to \Lambda e^+ \nu_e) = (3.63 \pm 0.38 \pm 0.??)\%$

scaled PDG: **(2.9±0.5)%**

- Statistics limited measurement.
  ➔ systematic error smaller than statistical
- Best precision to date

Summary

- **BEPCII/BESIII accumulated 567pb^{-1} data set @4.6GeV**
- **Open a door to study the lowest charmed baryon state Λ_c^+**
  - low backgrounds and high detection efficiency
- **Several physic potentials has been and is being explored**
  - absolute BFs of hadronic decays model-independently
  - Λ_c Semi-leptonic decays

Thank you!

谢谢！

Backup slides

Basic global fit logical

[Chinese Phys. C37(2013)106201]

$$N_i^{\rm ST} = N_{\Lambda_c^+\overline{\Lambda}_c^-} \cdot \mathcal{B}_i \cdot \varepsilon_i^{\rm ST}$$

$$N_{-j}^{\rm DT} = N_{\Lambda_c^+\overline{\Lambda}_c^-} \cdot \sum_i \mathcal{B}_i \cdot \mathcal{B}_j \cdot \varepsilon_{-j}^{\rm DT}$$

The efficiencies-corrected yields, denoted by $\mathbf{c} = \mathbf{E}^{-1}\mathbf{n}$

Based on the lease square principle, The χ^2 can be constructed as $\chi^2 \equiv (\mathbf{c} - \tilde{\mathbf{c}})^T \mathbf{V}_{\mathbf{c}}^{-1} (\mathbf{c} - \tilde{\mathbf{c}})$