Recent results of charmed baryon decays at Belle

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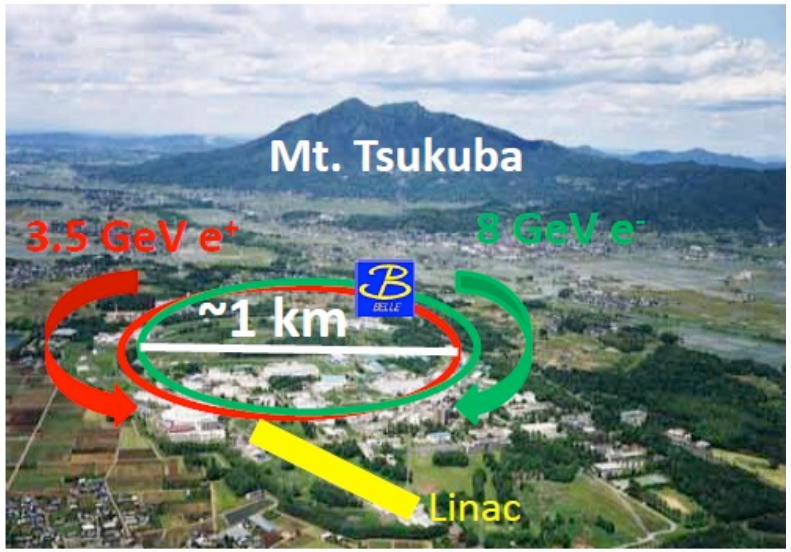
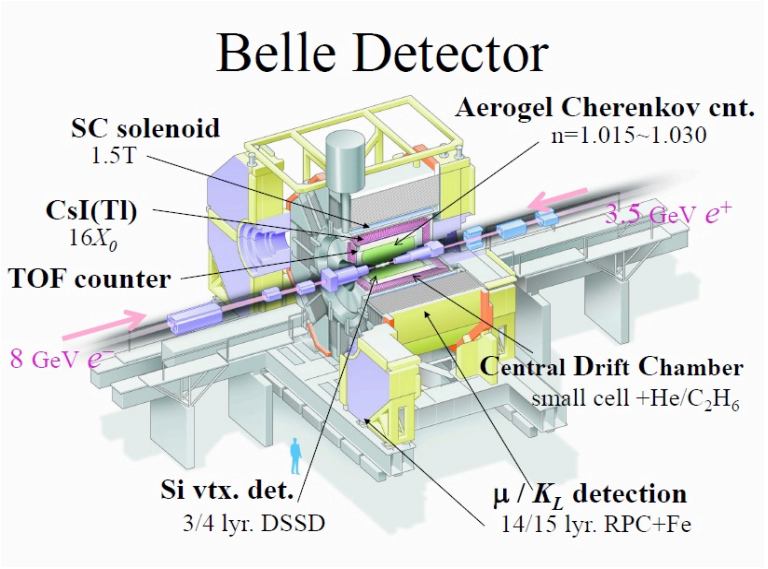
Outline:

- **Observation of DCS decay $\Lambda_c^+ \longrightarrow K^+\pi^-p$**
- **Search for $\Lambda_c^+ \longrightarrow \phi p\pi^0$ decays (hidden-strangeness penta-quark search)**
- **Branching fraction measurement of $\Lambda_c^+ \longrightarrow K^-\pi^+p\pi^0$ decays**

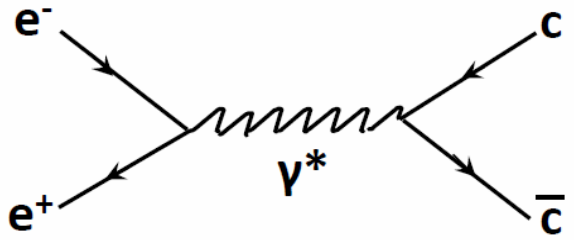
The Belle experiment runs at KEKB





$$e^- \rightarrow (*) \leftarrow e^+$$

- Charmed hadrons are mainly produced via

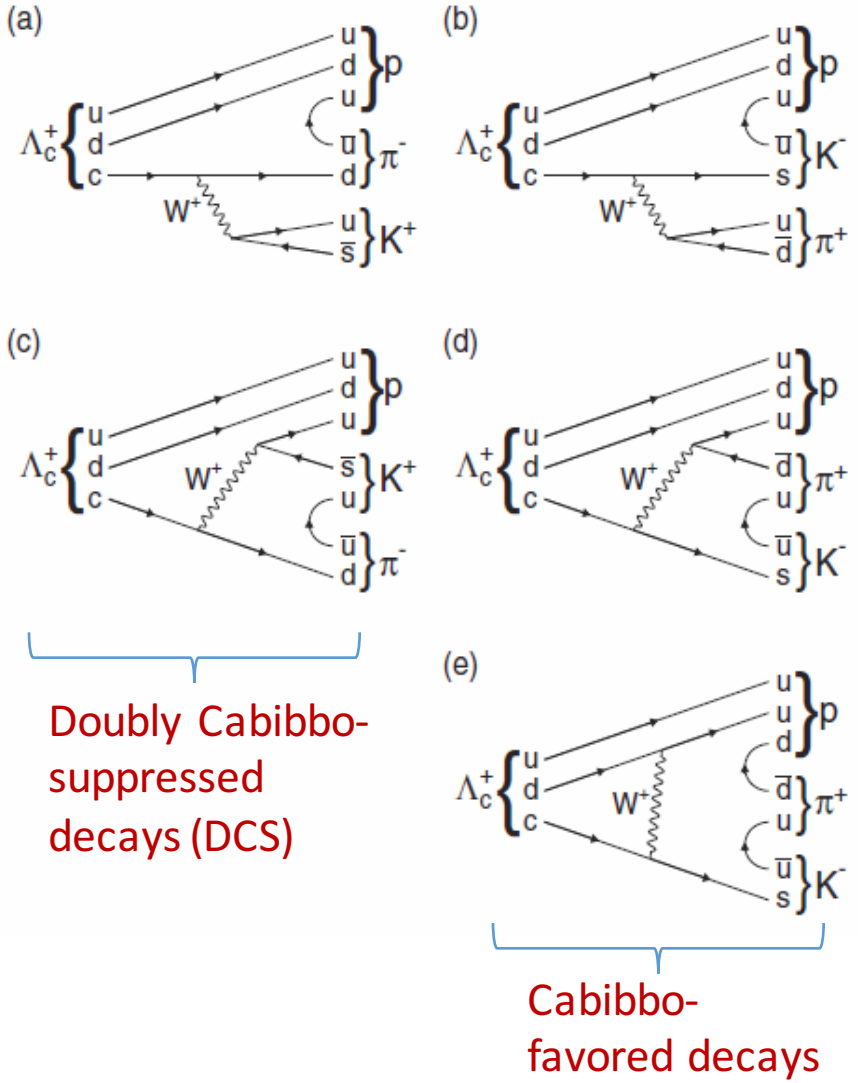


- Total integrated luminosity ~ 1000/fb
- Most of the data was taken at the $\Upsilon(4S)$ energy.

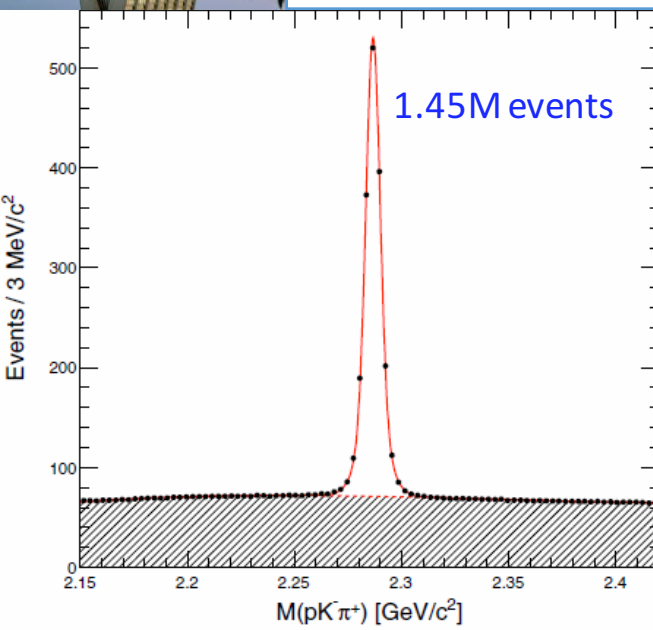
On resonance:	$\Upsilon(5S)$: 121 fb^{-1}
	$\Upsilon(4S)$: 711 fb^{-1}
	$\Upsilon(3S)$: 3 fb^{-1}
	$\Upsilon(2S)$: 25 fb^{-1}
	$\Upsilon(1S)$: 6 fb^{-1}
Off resonance/ scan:	~100 fb^{-1}

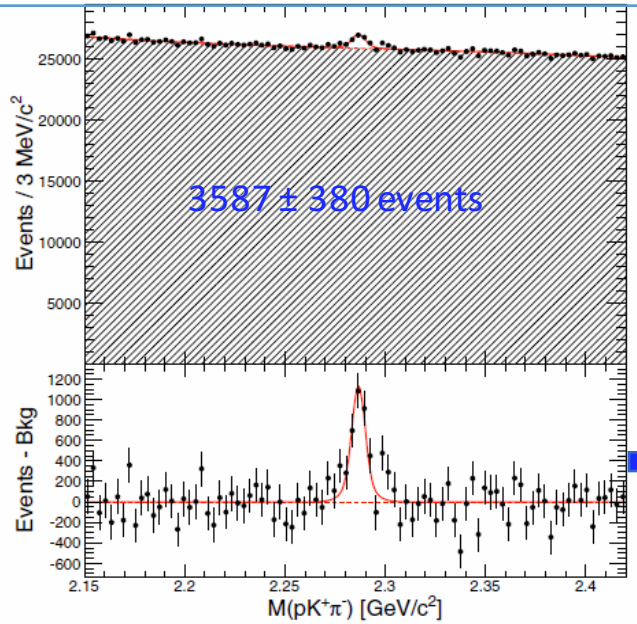
DCS $\Lambda_c^+ \longrightarrow pK^-\pi^+$ decays

- Double Cabibbo-suppressed (DCS) decays seen in charm mesons, but not previously in baryons.
  - One trial so far: $\frac{\mathrm{B}(\Lambda_c^+ \to pK^+\pi^-)}{\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+)} < 4.6\times10^{-3}$ at 90% CL by FOCUS [PLB 624, 166 (2005)]
- Naïve expectation: $\frac{\mathrm{B}(DCS)}{\mathrm{B}(CF)} = tan^4\theta_c = 0.285\%$
- Since W-exchange diagram is absent in DCS decay, $\frac{\mathcal{B}(DCS)}{\mathcal{B}(CF)}$ may be smaller than the naïve expectation.
- This analysis uses the entire Belle Data.



DCS $\Lambda_c^+ \to pK^-\pi^+$ decays





Residuals of the data with respect to fitted the combinatorial background

- $\Lambda_c^+ \to \Lambda(\to p\pi^-)K^+$ is a singly Cabibbo-suppressed (SCS) decay having the same final state as the DCS decays.
- Most of the SCS decays are suppressed by vertex cut. We estimate the contamination of the remaining SCS decays using $\frac{N(SCS)}{N(CF)} = \frac{\varepsilon(SCS)}{\varepsilon(CF)} \times \frac{B(SCS)}{B(CF)}$
- After subtraction, we observed 3379 ± 380 ± 78 DCS events with a significance > 9σ.

$$\frac{\mathcal{B}(\Lambda_c^+ \to pK^+\pi^-)}{\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)} = (2.35 \pm 0.27 \pm 0.21)\times 10^{-3}$$
$$= (0.82 \pm 0.12)\, tan^4\, \theta_c$$

(consistent within 1.5σ with the naïve expectation)

After subtracting the contribution $\Lambda^*(1520)$ and Δ isobar intermediates, which only contribute to CF decay, the revised ratio

$$\frac{\mathcal{B}(\Lambda_c^+ \to pK^+\pi^-)}{\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)} = (1.10 \pm 0.17)\, tan^4\, \theta_c$$

compatible with naïve expectation (within 1.0σ): no large W-exchange contribution in CF decay.

Absolute branching fraction

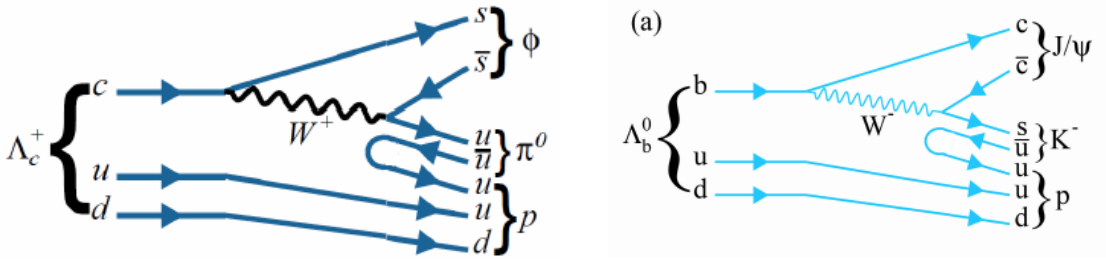
$$\mathcal{B}(\Lambda_c^+ \to pK^+\pi^-) = (1.61 \pm 0.23^{+0.07}_{-0.08})\times 10^{-4}$$

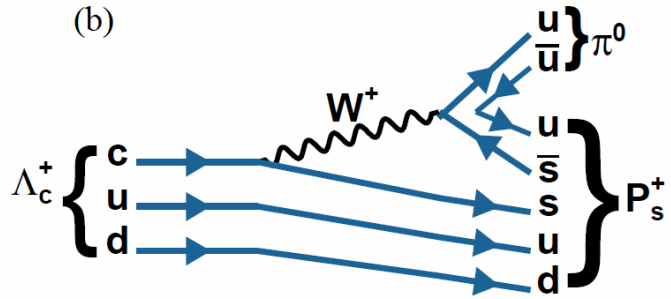
1st Observation

PRL 117, 011801 (2016)

Search for $\Lambda_c^+ \longrightarrow \phi p \pi^0$ decays

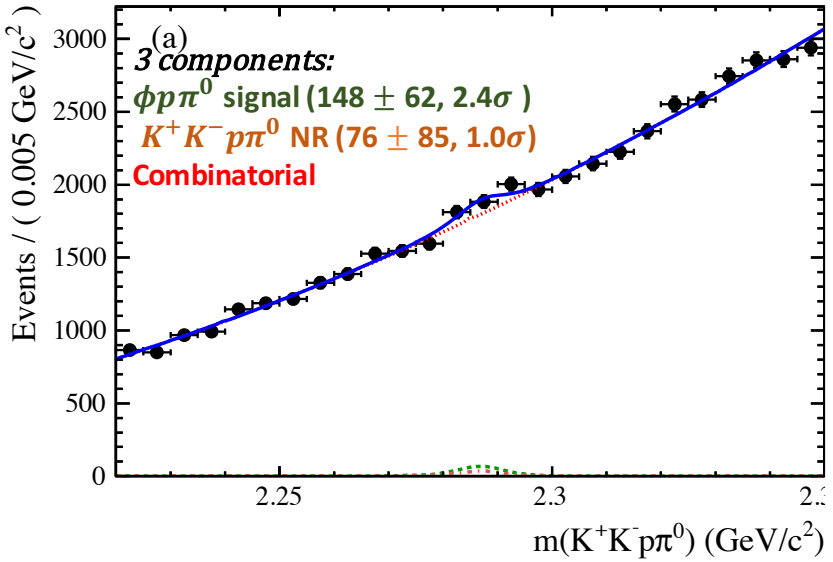
- The decay is similar to the decay of LHCb's hidden-charm penta-quark (P_c^+) discovery channel $\Lambda_b \to J/\psi p K^-$. [PRL 115, 072001 (2015
- Hidden-strangeness penta-quark (P_s^+) may appear in the intermediate state of ϕp, assuming the underlying mechanism creating the P_c^+ also holds for P_s^+, independent of the flavor and mass of P_s^+ is smaller than 2.151 GeV. [PRD 92, 114030 (2015)]

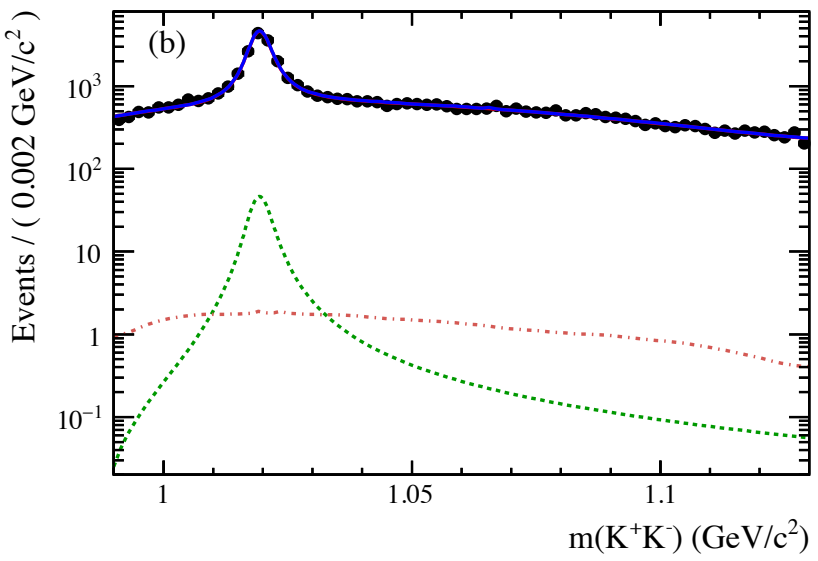


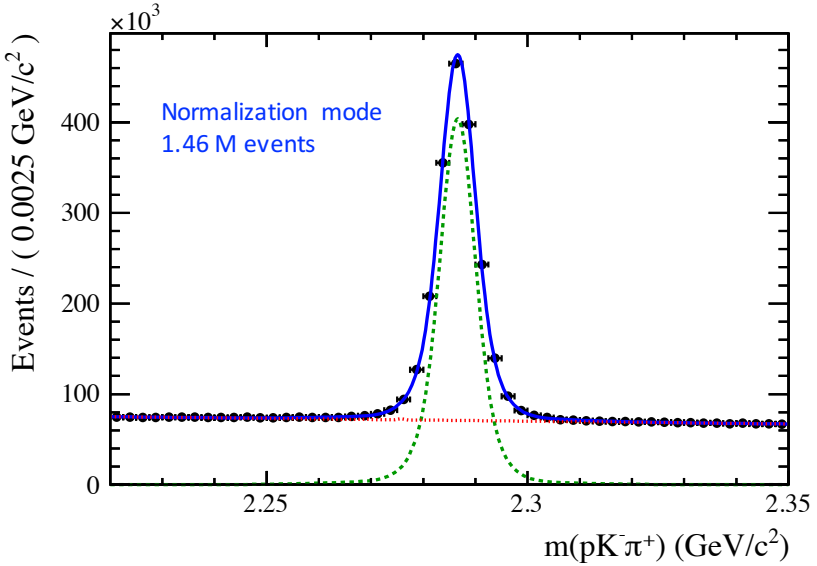


- LEPS & CLAS collaborations observed a bump at $\sqrt{s}$ ≈2.0 GeV in ϕ photo-production. [PRL 95, 182001(2005); PRC 89, 055208(2014); PRC 90, 019901 (2014)]
- This analysis uses 915/fb of Belle data collected at and near $\Upsilon(4S)$ and $\Upsilon(5S)$ resonances.

Search for $\Lambda_c^+ \longrightarrow \phi p\pi^0$ decays







- Two dimensional fit is performed to $K^+K^-p\pi^0$ and K^+K^- invariant masses, in order to extract the Λ_c^+ signal yield.
- Cabibbo-favored $\Lambda_c^+ \to \phi\Sigma^+(\to p\pi^0)$ decay has the same final state and is suppressed by rejecting the events in which $p\pi^0$ system has an invariant mass within 10 MeV of Σ^+ mass.
- Branching fraction is measured with respect to well measured CF decay $\Lambda_c^+ \to \pi^+K^-p$

$$\mathcal{B}(\Lambda_c^+ \to \text{final state}) = \frac{Y_{\text{Sig}}/\varepsilon_{\text{Sig}}}{Y_{\text{Norm}}/\varepsilon_{\text{Norm}}} \times \mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$$

90% CL Upper limits on branching fractions

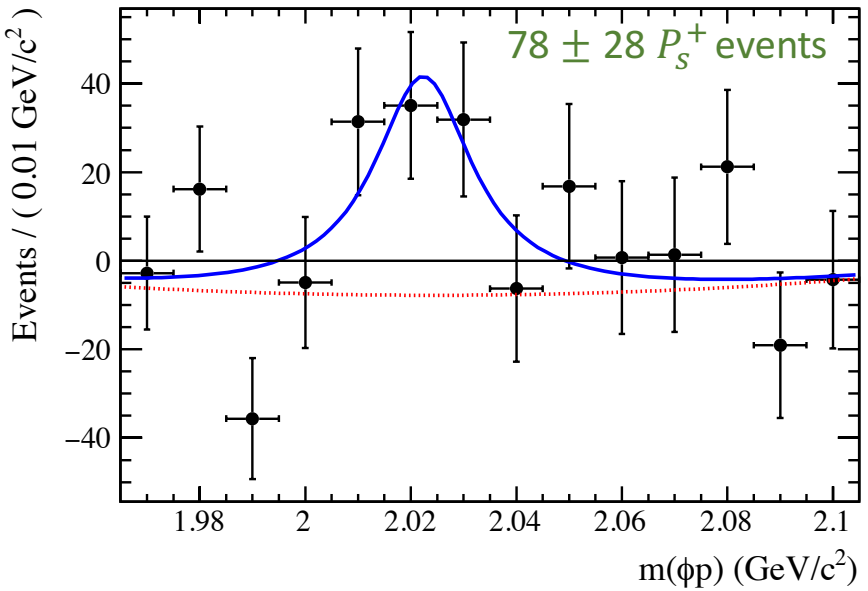
$$\mathcal{B}(\Lambda_c^+ \to \phi p\pi^0) < 15.3 \times 10^{-5},$$
$$\mathcal{B}(\Lambda_c^+ \to K^+K^-p\pi^0)_{\text{NR}} < 6.3 \times 10^{-5},$$

New

arXiv:1707.00089[hep-ex]
Submitted to PRD(RC)

Search for hidden-strangeness pentaquark

- 2D fits (slide # 6) are performed in bins of $\mathrm{m}(\phi p)$ for the background-subtracted $\mathrm{m}(\phi p)$ distribution.
- The distribution is then fitted with a RBW for P_s^+ and a phase space contribution obtained from MC simulation.
- The data shows (**no**) clear evidence of a P_s^+ state



M = 2.025 ± 0.005 GeV
Γ = 0.022 ± 0.012 GeV

90% CL Upper limits on product branching fractions

$$\mathcal{B}(\Lambda_c^+ \to P_s^+ \pi^0) \times \mathcal{B}(P_s^+ \to \phi p) \; < \; 8.3 \times 10^{-5}$$

New

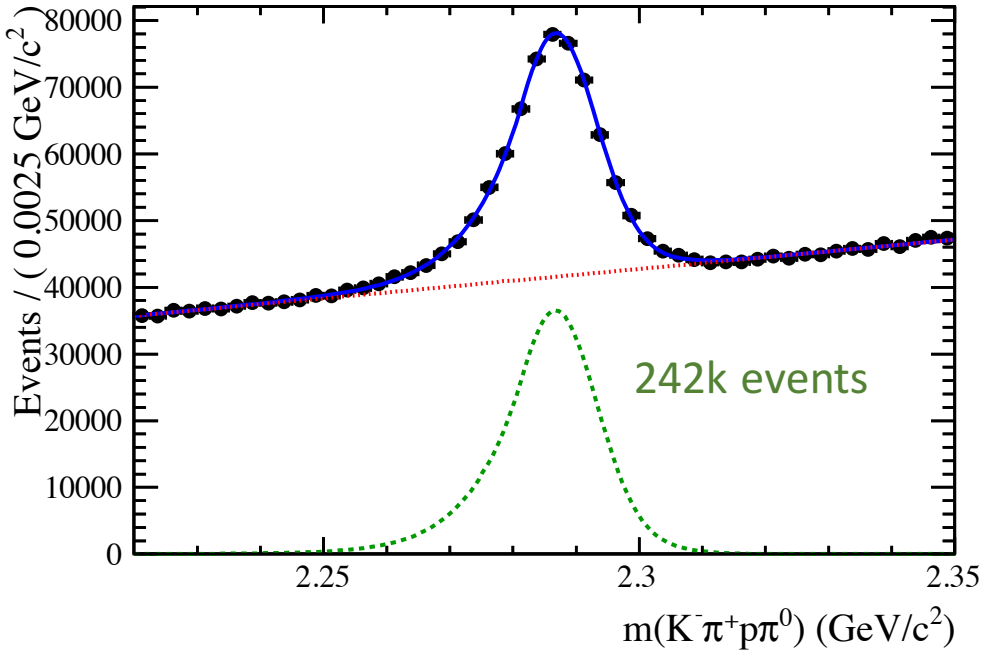
arXiv:1707.00089[hep-ex]
Submitted to PRD(RC)

This limit is a factor of 6 higher than the product branching measured by LHCb for an analogous hidden-charm pentaquark states $P_c^+(4450)$ $[(1.3 \pm 0.4)\times 10^{-5}]$

Branching fraction of $\Lambda_c^+ \to K^-\pi^+p\pi^0$

- CF decay $\Lambda_c^+ \to K^-\pi^+p\pi^0$ has the same final state topology and is used to adjust the MC-data differences in $\phi p\pi^0$ and $K^+K^-p\pi^0$ decays.

$$\frac{\mathcal{B}(\Lambda_c^+ \to K^-\pi^+p\pi^0)}{\mathcal{B}(\Lambda_c^+ \to K^-\pi^+p)} = (0.685 \pm 0.007 \pm 0.018)$$



Absolute branching fraction

New

$$\mathcal{B}(\Lambda_c^+ \to K^-\pi^+p\pi^0) = (4.42 \pm 0.05 \pm 0.12 \pm 0.16)\%,$$

arXiv:1707.00089[hep-ex]
Submitted to PRD(RC)

This is the most precise measurement to date.

Summary

- We have presented
  - The first observation of DCS baryonic decay $\Lambda_c^+ \to K^+\pi^-p$
  - The search for the decays $\Lambda_c^+ \longrightarrow \phi p\pi^0$ and NR $\Lambda_c^+ \longrightarrow K^+K^-p\pi^0$, no significant signal is observed for either decay mode and we set 90% CL upper limit on their branching fractions. These are the first such limit.
  - The search for hidden-strangeness pentaquark decay $P_s^+ \longrightarrow \phi p$, our data shows no clear evidence of this decay and we set an upper limit on product branching fraction. This is also first such search.
  - The most precise measurement of $B(\Lambda_c^+ \to K^-\pi^+p\pi^0)$.