Ω_c^0 two-body hadronic decays at LHCb

Chuangxin Lin (UCAS)

on behalf of the LHCb Collaboration

(Based on arXiv:2308.08512, LHCb-PAPER-2023-011)

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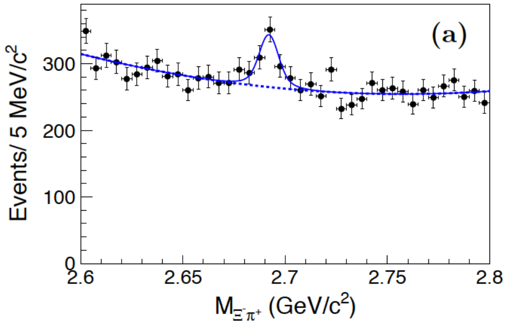
Outline

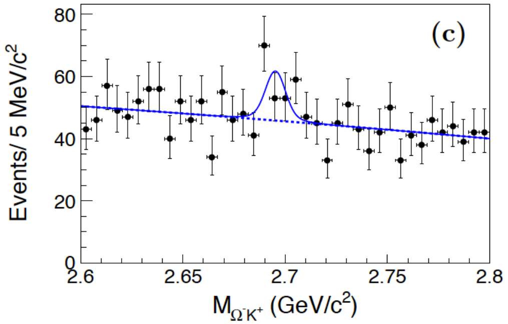
- Motivation
- LHCb experiment
- Strategy and dataset
- Selection and efficiency
- Signal yield
- Systematic uncertainty
- Results
- Summary

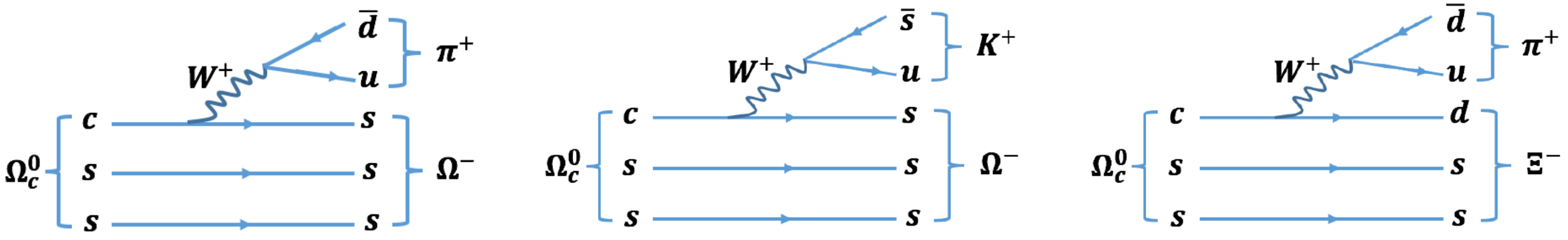
Motivation I

JHEP01(2023) 055
Phys. Rev. D 101, (2020) 094033
Eur. Phys. J. C. 80(2020) 1066
Chin. Phys. C 42, (2018) 093101
arXiv:2310.18896

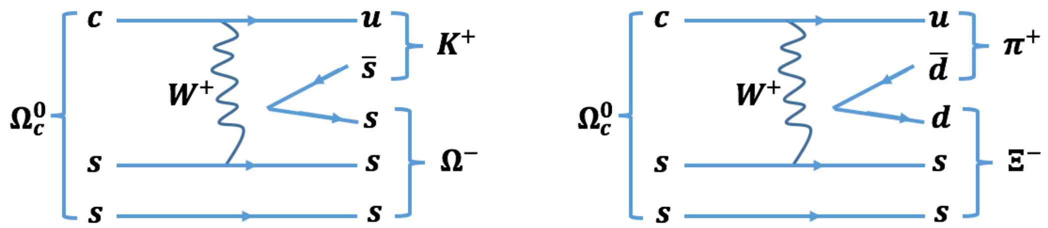
- Two-body SCS decays $\Omega_c^0 \to \Xi^-\pi^+$ and $\Omega_c^0 \to \Omega^-K^+$ not yet observed
- Results from Belle: Evidence of $\Omega_c^0 \to \Xi^-\pi^+$ (4.5σ) and upper limit of $\Omega_c^0 \to \Omega^-K^+$
- The BFs are crucial to test the theoretical models
  - Wide range of theoretical predictions for $\Xi^-\pi^+$ $(1.96\times10^{-3}\sim1.04\times10^{-1})$
  - No prediction is available for Ω^-K^+ (until our result submitted to arXiv)
  - Possibility to test factorizable and nonfactorizable contributions







W-emission: factorizable contribution

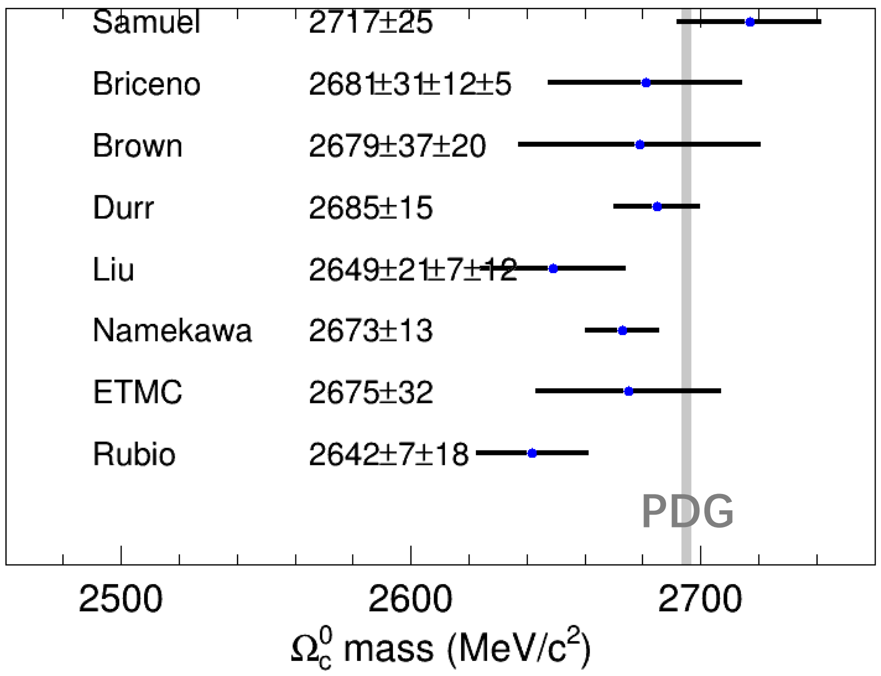


W-exchange: non-factorizable contribution

Motivation II

- Significant uncertainty in the experimental results of Ω_c^0 mass
- Theoretical predictions of Ω_c^0 mass in a wide range: 2610 ~ 2786 MeV/c^2
  - Lattice QCD
  - Other various models: $1/N_c$, bag model...

Λ_c^+ MASS	2286.46 ± 0.14 MeV	
Ξ_c^+ MASS	2467.71 ± 0.23 MeV	(S = 1.3)
Ξ_c^0 MASS	2470.44 ± 0.28 MeV	(S = 1.2)
Ω_c^0 MASS	2695.2 ± 1.7 MeV	(S = 1.3)



PDG2023
arXiv:2309.04401
arXiv:1207.3536
arXiv:1409.0497
arXiv:0909.3294
arXiv:1208.6270
arXiv:1301.4743
arXiv:1503.08440
Phys. Lett. B 175 (1986) 197
PhysRevD.54.4515 (1996)
PhysRevD.52.1722 (1995)
Phys. Lett. B 355 (1995) 345
Phys. Lett. B 251 (1990) 597
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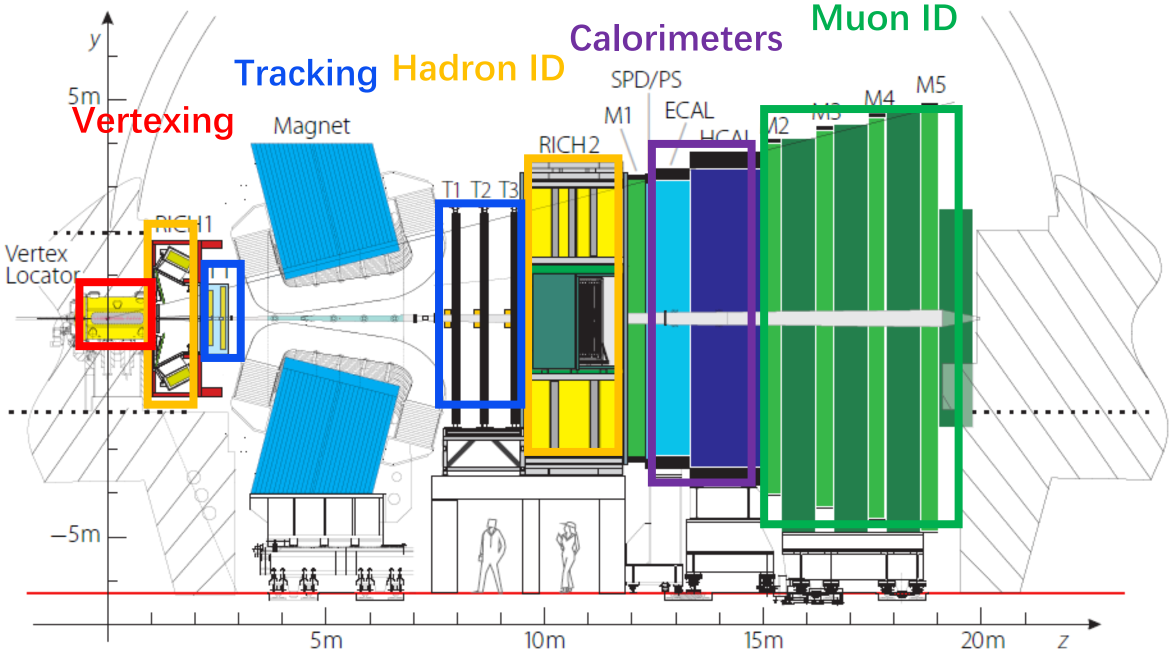
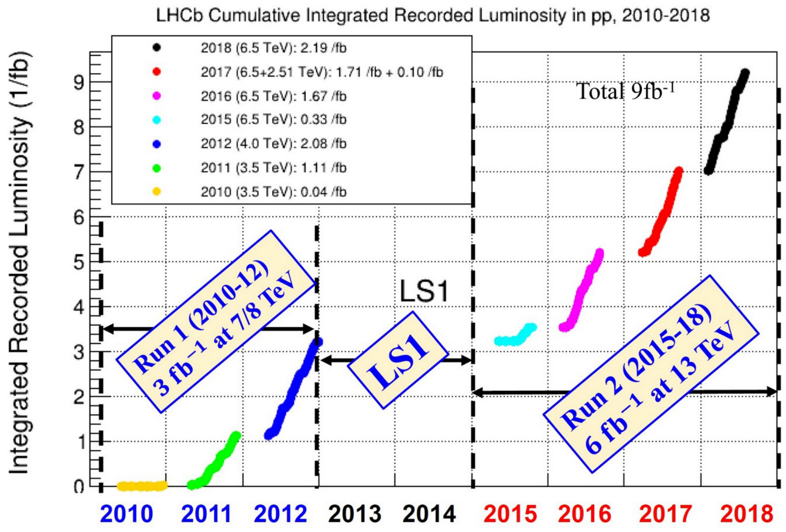
The LHCb experiment

JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022





- Single arm spectrometer, 25% of $b\bar{b}$ pairs produced in the acceptance
- Designed to study heavy hadron decays, high rapidity ($2 < \eta < 5$) and low p_{T}
- Excellent vertexing, tracking, momentum resolution and particle identification

Strategy and dataset

- Normalization mode $\Omega_c^0 \to \Omega^- \pi^+$ used
  - Same decay topology and high yield

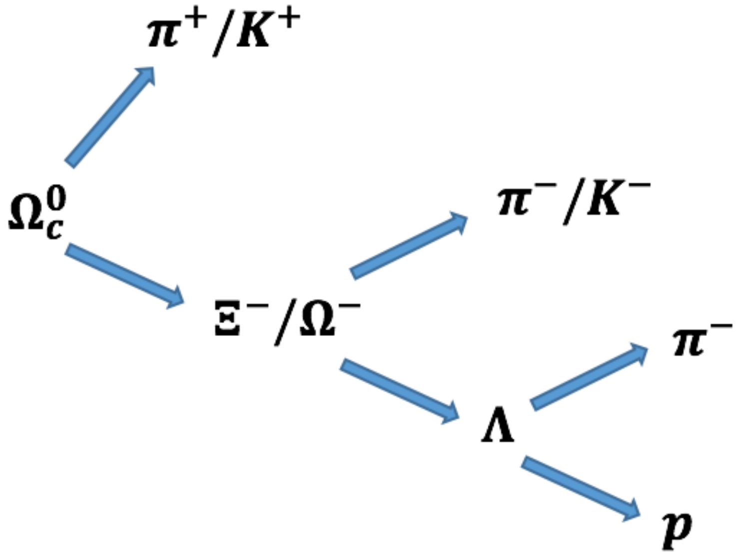
- $$\frac{\mathcal{B}(\Omega_c^0 \to \Omega^- K^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)} = \frac{N_{\Omega_c^0 \to \Omega^- K^+}}{N_{\Omega_c^0 \to \Omega^- \pi^+}} \frac{\epsilon_{\Omega_c^0 \to \Omega^- \pi^+}}{\epsilon_{\Omega_c^0 \to \Omega^- K^+}}, \quad \frac{\mathcal{B}(\Omega_c^0 \to \Xi^- \pi^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)} = \frac{N_{\Omega_c^0 \to \Xi^- \pi^+}}{N_{\Omega_c^0 \to \Omega^- \pi^+}} \frac{\epsilon_{\Omega_c^0 \to \Omega^- \pi^+}}{\epsilon_{\Omega_c^0 \to \Xi^- \pi^+}} \frac{\mathcal{B}(\Omega^- \to \Lambda K^-)}{\mathcal{B}(\Xi^- \to \Lambda \pi^-)}$$
  - Yields → Invariant mass fits
  - Efficiencies → Calculate using simulation
  - Branching fractions → PDG

$\mathcal{B}(\Xi^- \to \Lambda\pi^-)$	$(67.8 \pm 0.7)\%$
$\mathcal{B}(\Omega^- \to \Lambda K^-)$	$(99.887 \pm 0.035)\%$

- Perform analysis based on Run II 2016-2018 dataset ($5.4\ \text{fb}^{-1}$)
- Simulation samples are used to optimize selections and estimate the efficiencies

Selection and efficiency

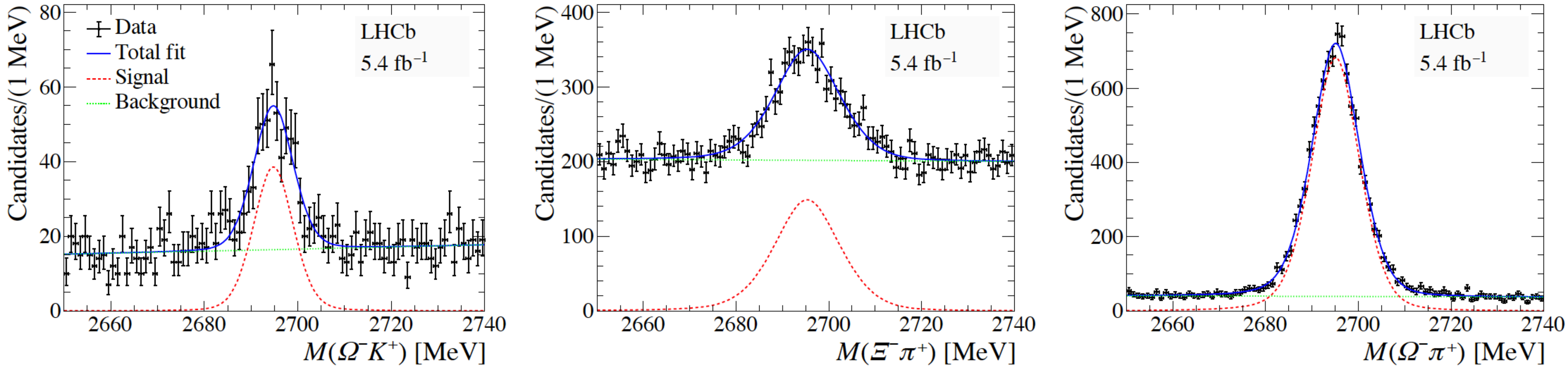
- Cut-based selection requirements are performed on the final-state charged tracks, Λ, Ξ^-/Ω^- and Ω_c^0 to suppress combinatorial backgrounds
- A kinematic fit of the decay chain constrains the Ω_c^0 to originate from PV, and the Ξ^-/Ω^- and Λ to have their known masses
- Efficiencies obtained after applying selections and simulation corrections



Signal yield

arXiv:2308.08512
LHCb-PAPER-2023-011

- Extended unbinned maximum likelihood fits are performed to full dataset
- Signal is modelled by a Johnson S_U distribution and a Gaussian function, the tail and fraction of Johnson S_U are fixed from simulation sample
- Background is modelled by an Exponential function



Decay mode	$\Omega_c^0 \to \Omega^- K^+$	$\Omega_c^0 \to \Xi^- \pi^+$	$\Omega_c^0 \to \Omega^- \pi^+$
Signal yield	425 ± 35	2780 ± 150	9330 ± 110

Systematic uncertainty

- The total uncertainty is determined from the sum of all contributions in quadrature

Table 1: Systematic uncertainties for the Ω_c^0 mass measurement.

Source	Uncertainty [MeV]
Momentum scale calibration	0.27
Energy loss correction	0.03
Fit model	0.01
Total	0.27
External input masses	0.30

Table 2: Systematic uncertainties (in percent) for the BF ratio measurement.

Source	$\mathcal{B}(\Omega^- K^+)/\mathcal{B}(\Omega^-\pi^+)$	$\mathcal{B}(\Xi^-\pi^+)/\mathcal{B}(\Omega^-\pi^+)$
Tracking efficiency	1.78	1.78
PID efficiency	3.37	0.62
Trigger efficiency	1.26	0.69
Fit model	0.16	0.54
Decay model	3.59	1.32
Lifetimes of Ω^- and Ξ^-	-	0.59
Simulation sample size	0.07	0.08
Reweight strategy	2.82	0.52
Mass resolution	2.35	0.97
Total	6.51	2.76
External input BFs	-	1.04

Results

- The BF ratios of $\Omega_c^0 \to \Omega^- K^+$ and $\Omega_c^0 \to \Xi^- \pi^+$ are measured to be
  - $\frac{\mathcal{B}(\Omega_c^0 \to \Omega^- K^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)} = 0.0608 \pm 0.0051(\mathrm{stat}) \pm 0.0039(\mathrm{syst})$
  - $\frac{\mathcal{B}(\Omega_c^0 \to \Xi^- \pi^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)} = 0.1581 \pm 0.0087(\mathrm{stat}) \pm 0.0044(\mathrm{syst}) \pm 0.0016(\mathrm{ext})$

- Using $\Omega_c^0 \to \Omega^- \pi^+$ decay, the Ω_c^0 mass is measured to be
  - $m(\Omega_c^0) = 2695.28 \pm 0.07(\mathrm{stat}) \pm 0.27(\mathrm{syst}) \pm 0.30(\mathrm{ext})\ [\mathrm{MeV}/c^2]$

Summary I

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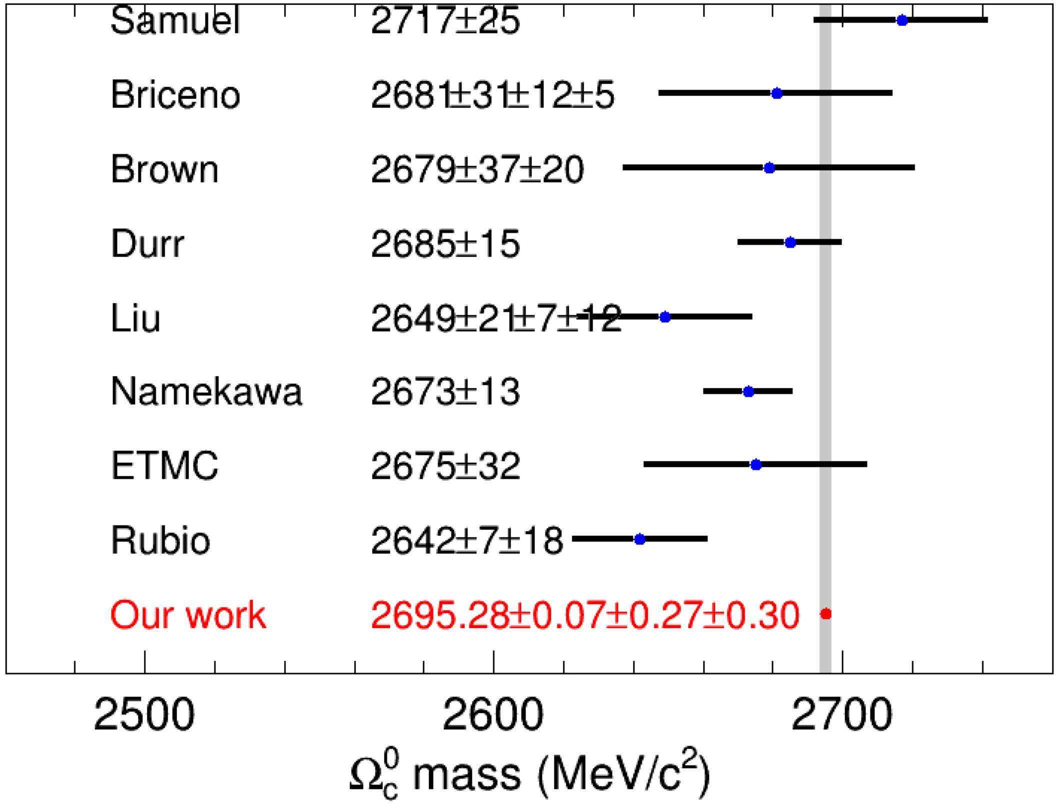
- Using LHCb Run II dataset (2016-2018, $5.4\ \mathrm{fb}^{-1}$)
- The first observation of the $\Omega_c^0 \to \Omega^- K^+$ and $\Omega_c^0 \to \Xi^- \pi^+$ SCS decays is reported

BF ratios	This work	CA model	LFQM	Naive estimation
$\frac{\mathcal{B}(\Omega_c^0 \to \Omega^- K^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)}$	0.0608 ± 0.0064	-	-	0.0467
$\frac{\mathcal{B}(\Omega_c^0 \to \Xi^- \pi^+)}{\mathcal{B}(\Omega_c^0 \to \Omega^- \pi^+)}$	0.1581 ± 0.0099	0.1038	0.0345	-

- The non-factorizable contributions are necessary to accurately calculate the BFs
- Provides fresh inputs to understand the non-perturbative effects in models based on QCD.

Summary II

- The precision of Ω_c^0 mass improved by four times
  - $m(\Omega_c^0) = 2695.28 \pm 0.07(\text{stat}) \pm 0.27(\text{syst}) \pm 0.30(\text{ext})$ [MeV/c^2]
  - This Ω_c^0 mass measurement provides a strict constraint on various theoretical models



Thank you!

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