CP Asymmetry Measurement in $\Xi_c^+ \to \Sigma^+\pi^+\pi^-$ at Belle II

Anil Panta

University of Mississippi

Belle II Experiment

- The Belle II experiment is the successor of very successful Belle experiment
- Uses Super-KEKB accelerator in Tsukuba, Japan
- More than 400 /fb data on tape.

$$c\bar{c},\ u\bar{u},\ d\bar{d},\ s\bar{s},\ l^+l^- \leftarrow e^+e^- \to \Upsilon(4S) \to B\bar{B}$$

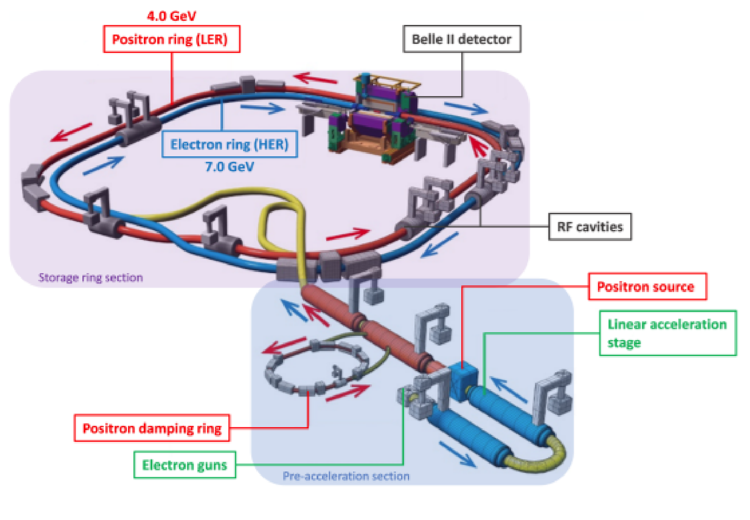


Figure: Super-KEKB Accelerator

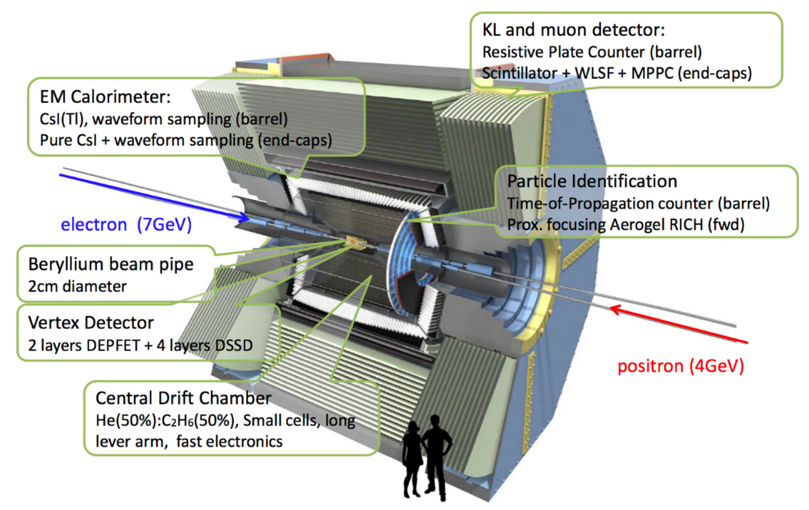


Figure: Belle-II Detector

Motivation and Formalism

The amount of CP violation in the Standard Model (SM) is not enough to explain baryogenesis. Charge-Parity Violation within SM of charm decay is expected to be small (10^{-4} - 10^{-3}).Very few measurement have been made in the charm baryon system. (compare to Meson sector)

- In 2018 LHCb measured CP asymmetries in Λ_c^+ decays [1]

$$\Delta A_{CP}^{wgt} = A_{CP}(pK^-K^+) - A_{CP}^{wgt}(p\pi^+\pi^-) = (0.03 \pm 0.91 \pm 0.61)\%$$

- These modes are related to Singly Cabibbo suppressed $\Xi_c^+ \to \Sigma^+h^+h^-$ (h π, K) via U-spin (exchange of d and s quarks) sum rule.

$$A_{CP}(\Lambda_c \to pK^-K^+) + A_{CP}(\Xi_c^+ \to \Sigma^+\pi^+\pi^-) = 0$$
$$A_{CP}(\Lambda_c \to p\pi^+\pi^-) + A_{CP}(\Xi_c^+ \to \Sigma^+K^+K^-) = 0$$

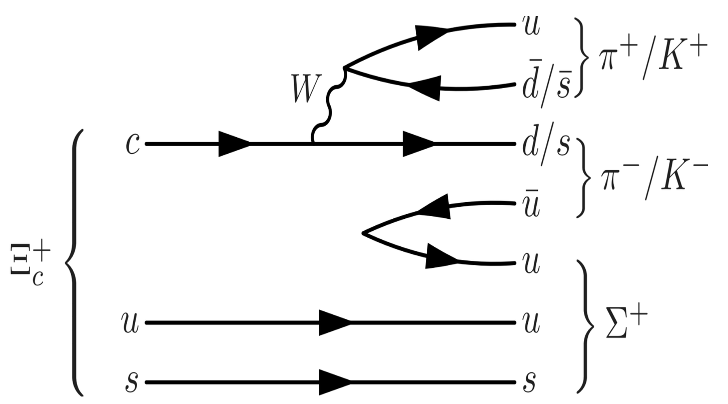


Figure: Tree Level Diagram

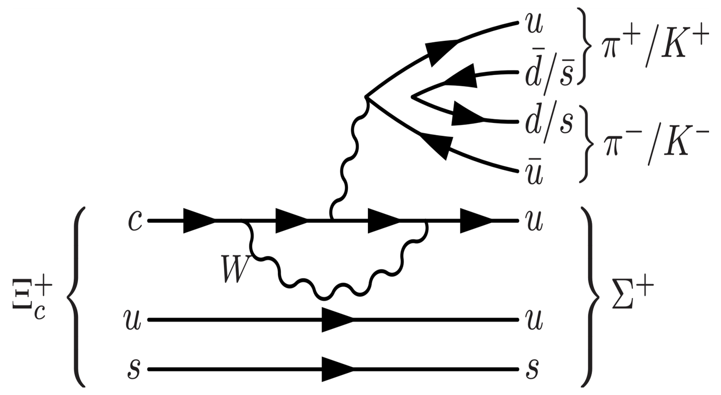


Figure: Loop Level Diagram

- Raw asymmetry from number counting

$$A_{raw}^{\Xi_c} = \frac{N(\Xi_c^+ \to \Sigma^+\pi^+\pi^-) - N(\Xi_c^- \to \overline{\Sigma}^-\pi^-\pi^+)}{N(\Xi_c^+ \to \Sigma^+\pi^+\pi^-) + N(\Xi_c^- \to \overline{\Sigma}^-\pi^-\pi^+)}$$

- Raw asymmetry includes effects from CP asymmetries, production (forward-backward), and detection asymmetries

$$A_{raw}^{\Xi_c} = A_{CP}^{\Xi_c} + A_{FB}^{\Xi_c} + A_\Sigma + A_p,$$

- The forward-backward asymmetry anti-symmetric as a function of $cos(\theta)$
- Take difference with CF control channel of $\Lambda_c^+ \to \Sigma^+\pi^+\pi^-$ to cancel the detection asymmetry

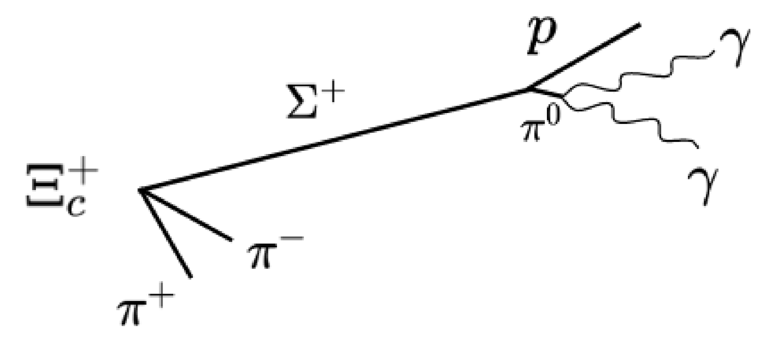
$$A_{raw}^{\Lambda_c} = A_{FB}^{\Lambda_c} + A_\Sigma + A_p$$

- Isolate CP asymmetry for signal mode

$$A_{CP}^{\Xi_c} = \frac{A_{raw}^{\Xi_c}(cos(\theta^*_{\Xi_c})) + A_{raw}^{\Xi_c}(-cos(\theta^*_{\Xi_c}))}{2} - \frac{A_{raw}^{\Lambda_c}(cos(\theta^*_{\Lambda_c})) + A_{raw}^{\Lambda_c}(-cos(\theta^*_{\Lambda_c}))}{2}$$
$$= A_1 - A_2$$

Event Selection

The decay chain of interest is: $\Xi_c^+ \to (\Sigma^+ \to p(\pi^0 \to \gamma\gamma))\pi^+\pi^-$.
Sample size: 400 /fb.
At the reconstruction level, very loose selection criteria has been applied. Same cut for both signal and control channel except for the mass range of particle cut. A cut on the pre-trained multi-variate algorithm (MVA) is applied to remove the candidate coming from Fake Photons and Beam Background Photons



Decay Chain

Description	Selection criteria
charged track	in CDC acceptance
$\pi^\pm$ p	minimum number(>0) of hits in CDC
p	proton PID > 0.9
γ	Certain minimum energy required on calorimeter
π^0	0.120 < M < 0.145 [GeV/c^2]
Σ^+	1.159 < M < 1.219 [GeV/c^2]
Ξ_c (Λ_c)	CM momentum>= 2.5 [GeV/c] 2.4 < M < 2.54 [GeV/c^2] (2.24 < M < 2.33)
treeFit Ξ_c (Λ_c)	chiProb > 0.001 mass-constrain Σ^+

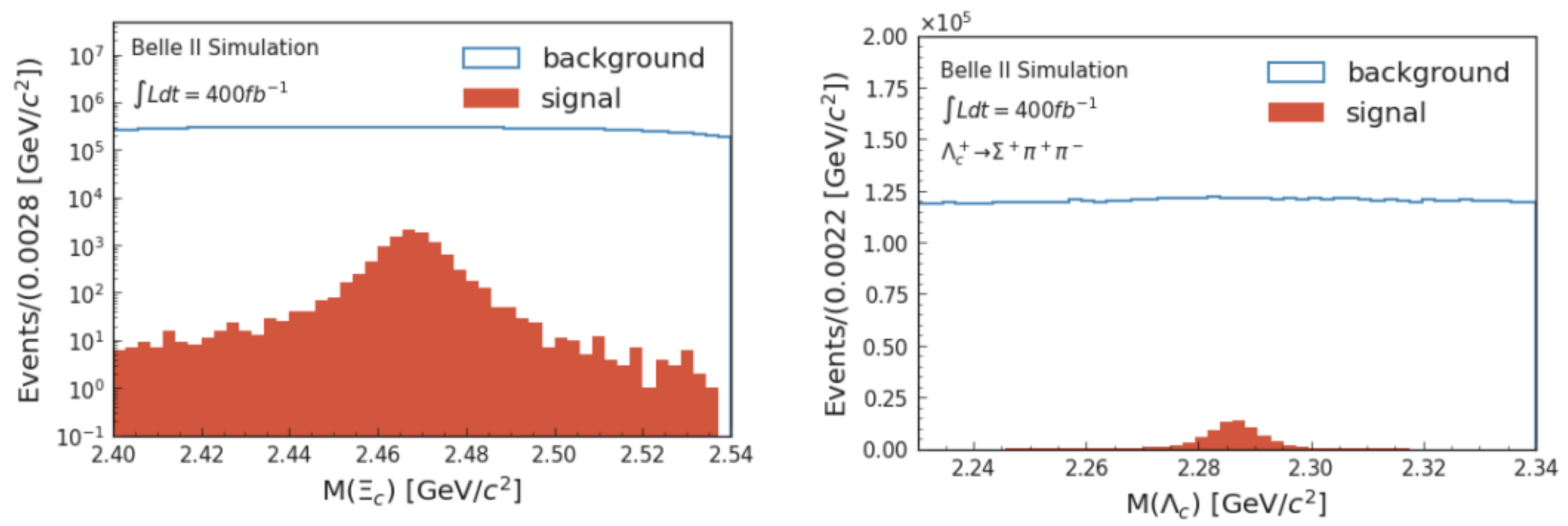


FIG. 4: Non-Stacked Mass plot for Ξ_c^+ (left) and Λ_c^+ (right) at reconstruction level.

Fast Boosted Decision Tree (BDT)

To separate signal and background we use a multi-variate algorithm (MVA) called FastBDT. Traning is done set of uncorrelated variables as: flight distance of Σ^+, dr(transverse distance in respect to IP for a vertex) and dz(z-component of the point of closest approach (POCA) with respect to the interaction point) of $\pi^\pm$, cluster energy ratio (E9E21) of photons, Center of Mass Momentum of π^0 and χ^2 of vertex TreeFit.

- Over-training check performed using Kolmogorov-Smirnov test.

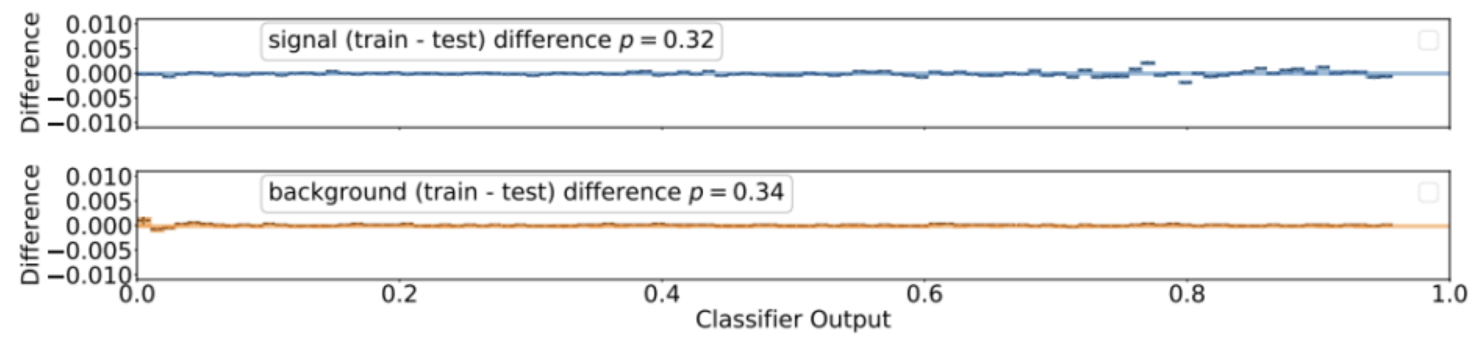
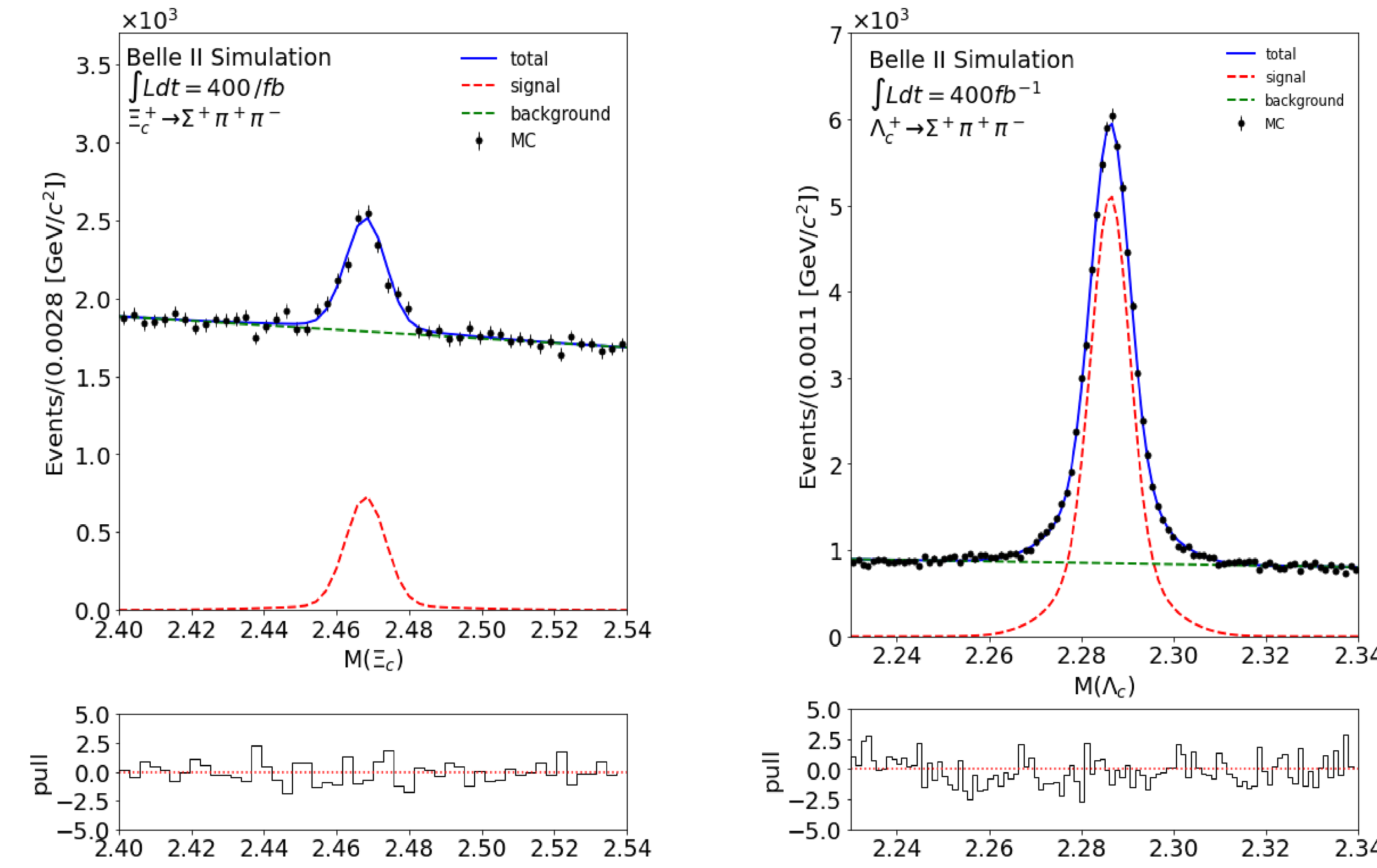


Figure: Overtraining Check where p is K-S test value.

Fit Strategy and Result

- Fit to the whole mass sample is performed.
- Model: Double Gaussian for signal and 1st order polynomial for background.
- Simultaneous fit in bins $cos(\theta^*)$ for particle and anti particle separately fixing signal pdf.



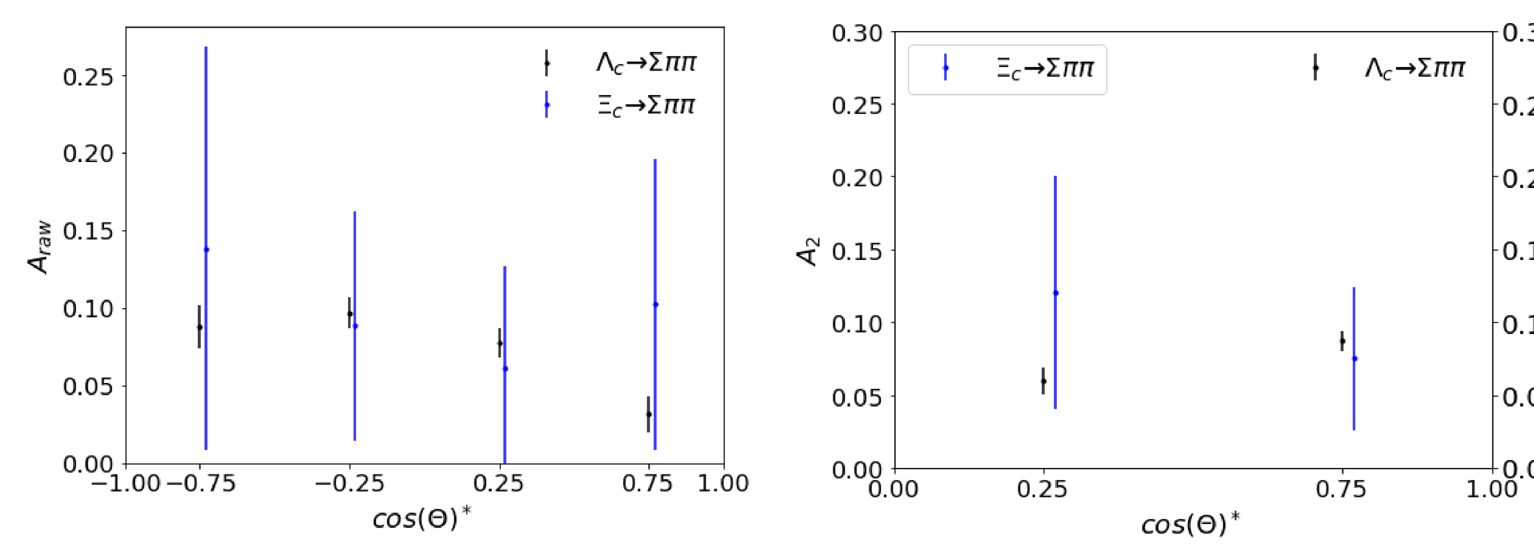


Figure: Raw Asymmetry (left) and average of folded Raw Asymmetry (right)

CP Asymmetry Result in Monte Carlo

In 400 /fb MC we get the number consistent with zero.

$$A_{CP}^{\Xi_c} = (2.61 \pm 4.73)\%$$

- Data - MC check in control channel is done and tested. We are finalizing the Systematic.
- Targeting the publication for summer and is first measurement.

References

[1] LHCb collaboration. *arXiv:1901.01776 [hep-ph]*.

Guided by

Dr. Jake Bennett , Assistant Professor, University of Mississippi
Dr. Longke Li, Post-Doc, KEK

In part done with OZAKI Fellowship.
This work was supported by U.S. DOE and research Award No. DE-SC0021274 .