超级陶粲装置
Super Tau-Charm Facility

Search for CPV in $\Xi(-,0)$ decays in $J/\psi \to \Xi\bar{\Xi}$ decays

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Outline

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- Formalism & MC production
- Event selection
- BESIII & STCF comparisons
- Summary

Introduction

- CP violation(CPV) has been observed in K, B, D meson systems and Λ_b^0 baryon system. However, further searches for CPV in other baryon decays remain crucial for discovering additional sources of CPV beyond the Standard Model.
- Measurement of asymmetry parameters of hyperon weak decay can be used to test the CP violation

$$\alpha = \frac{2Re\left(A_S^* \cdot A_p\right)}{|A_S|^2 + |A_P|^2} \qquad \frac{dN}{d\Omega} \propto 1 + \alpha \overrightarrow{P_Y} \cdot \hat{p}_d \qquad A_{CP} = \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}}$$

($\mathcal{O}^{\Xi} \sim 10^{-5}$)

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- The multi-step decay chain $e^+e^- \rightarrow J/\psi \rightarrow \Xi^-\bar{\Xi}^+$ offers us much more experimental information than Λ decay. And this decay features a multi-particle final state, making it useful for evaluating OSCAR's performance.

Formalism & MC production

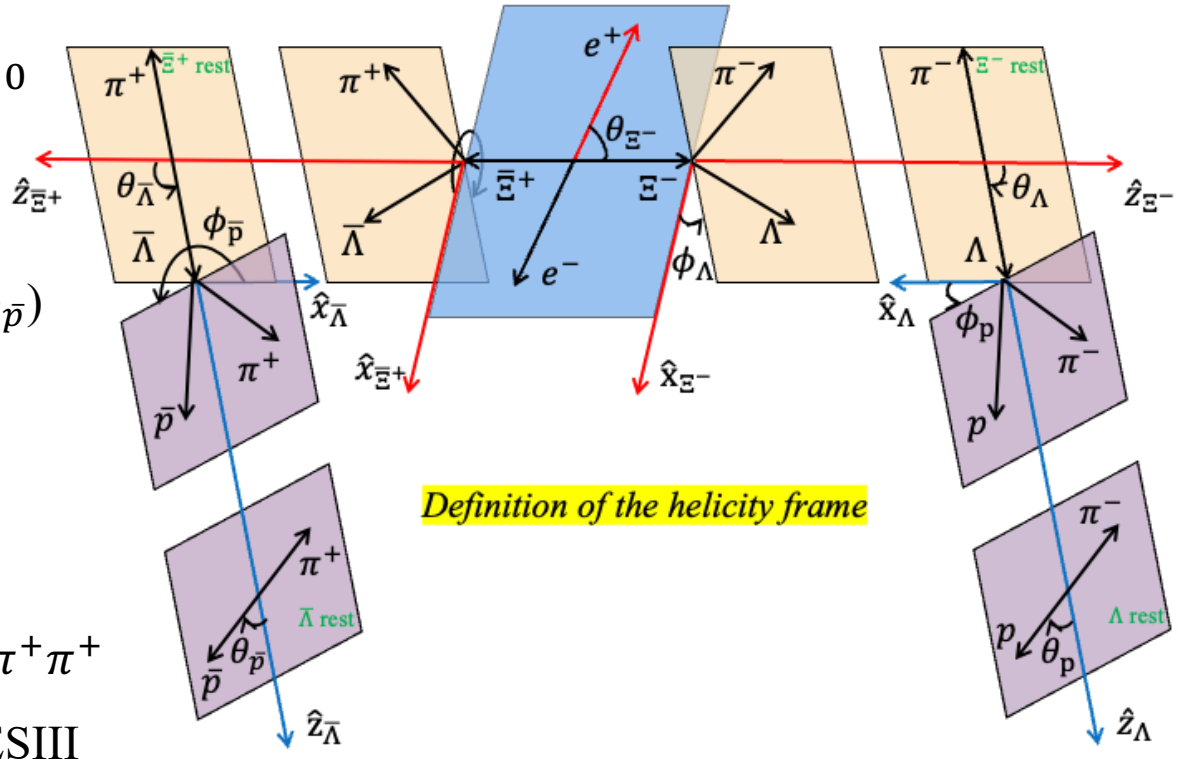
- Angular distribution:

  Phys. Rev. D 99, 056008 (2019)

$$\mathcal{W}(\xi;\omega) = \sum_{\mu,\bar{\nu}=0}^{3}\sum_{\mu'=0}^{3}\sum_{\bar{\nu}'=0}^{3} C_{\mu\bar{\nu}} a^{\Xi}_{\mu\mu'} a^{\Lambda}_{\mu'0} a^{\bar{\Xi}}_{\bar{\nu}\bar{\nu}'} a^{\bar{\Lambda}}_{\bar{\nu}'0}$$

  - Parameters: $(\alpha_{J/\psi},\ \Delta\Phi,\ \alpha_{\Xi},\ \bar{\alpha}_{\Xi},\ \phi_{\Xi},\ \bar{\phi}_{\Xi},\ \alpha_{\Lambda},\ \bar{\alpha}_{\Lambda})$
  - Helicity angles: $(\theta_{\Xi},\ \theta_{\Lambda},\ \phi_{\Lambda},\ \theta_{\bar{\Lambda}},\ \phi_{\bar{\Lambda}},\ \theta_{p},\ \phi_{p},\ \theta_{\bar{p}},\ \phi_{\bar{p}})$

- Signal MC production
  - OSCAR version: 2.6.2 updated (git download date:2025/06/25)
  - Signal channel: $J/\psi \to \Xi^-\bar{\Xi}^+ \to \Lambda\pi^-\bar{\Lambda}\pi^+ \to p\pi^-\pi^-\bar{p}\pi^+\pi^+$
  - 0.2 million DIYMC with the input parameters from BESIII publication *Nature 606, 64–69 (2022)*



Event selection

- Charged tracks
  - $|cos\theta| < 0.93$
  - No requirement for vertex
  - $N_{\mathrm{poz}} \geq 3$ & $N_{\mathrm{neg}} \geq 3$
- Proton and pion selection:
  - For N_{poz}:
    - p: $p > 0.3$ GeV/c
    - π^+: $p < 0.3$ GeV/c
  - For N_{neg}:
    - $\bar{p}$: $p > 0.3$ GeV/c
    - π^-: $p < 0.3$ GeV/c
- Λ、Ξ^- reconstruction
  - Loop p and π^- candidates
  - Λ : vertex fit
  - Ξ^-: vertex fit and second vertex fit
  - The best Λ and Ξ^- candidates from combination with minimum $\sqrt{\left(m_{p\pi^-} - M_\Lambda\right)^2 + \left(m_{p\pi^-\pi^-} - M_\Xi\right)^2}$
- $\bar{\Lambda}$、$\bar{\Xi}^+$ reconstruction
  - Loop $\bar{p}$ and π^+ candidates
  - $\bar{\Lambda}$: vertex fit
  - $\bar{\Xi}^+$: vertex fit and second vertex fit
  - The best $\bar{\Lambda}$ and $\bar{\Xi}^+$ candidates from combination with minimum $\sqrt{\left(m_{\bar{p}\pi^+} - M_\Lambda\right)^2 + \left(m_{\bar{p}\pi^+\pi^+} - M_\Xi\right)^2}$
- 4C kinematic fit
  - Do kinematic fit on Ξ^- $\bar{\Xi}^+$

The selection criteria are the same as BESIII

BESIII & STCF comparisons

Cut flow comparison

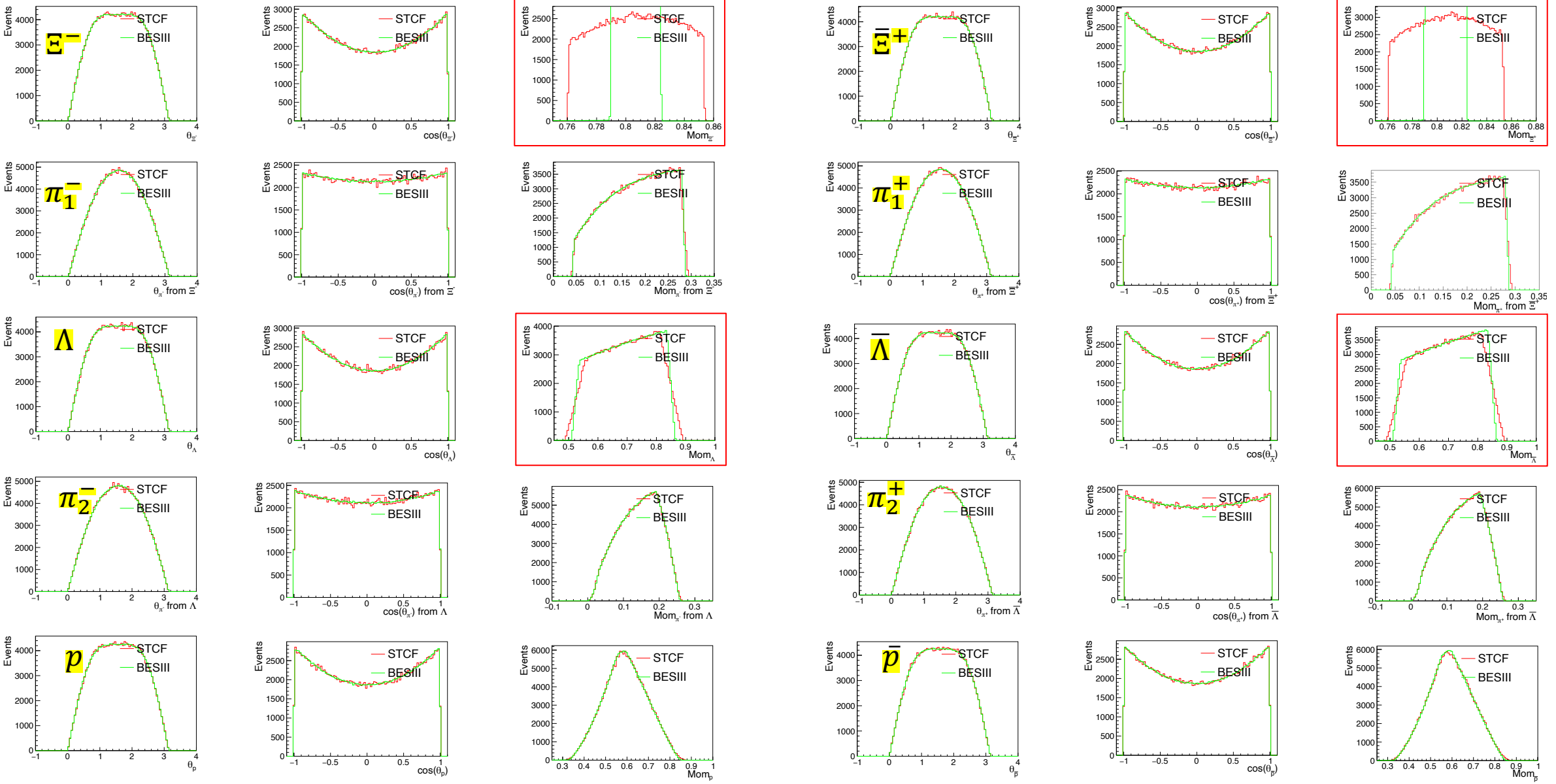
- No background mix in OSCAR

BESIII Signal MC	09+12+18+19 Events	09+12+18+19 Eff. (%)	Re. Eff.(%)
	9,000,000	100.0	
Charged tracks	3057857	34.0	
Λ、Ξ^- reconstruction	2545353	28.3	83.2
$\bar{\Lambda}$、$\bar{\Xi}^+$ reconstruction	2092432	23.2	82.2
4C kinematic fit	1724213	19.2	82.4

OSCAR Signal MC	Events	Eff. (%)	Re. Eff.(%)
	200,000	100.0	
Charged tracks	106291	53.1	
Λ、Ξ^- reconstruction	85234	42.6	80.2
$\bar{\Lambda}$、$\bar{\Xi}^+$ reconstruction	68657	34.3	80.6
4C kinematic fit	44617	22.3	65.0

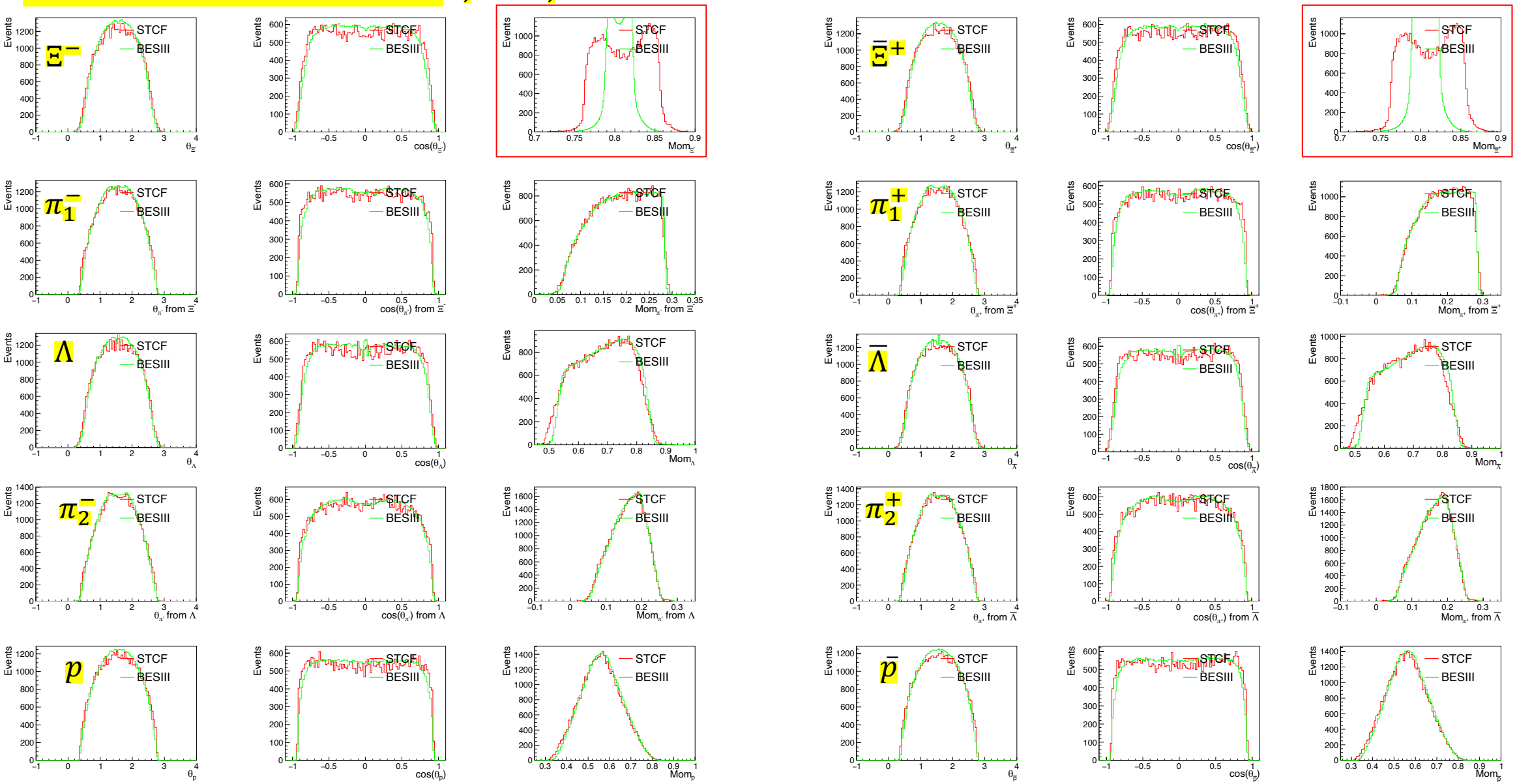
BESIII & STCF comparisons

In Truth level: check θ, $cos\theta$, Mom



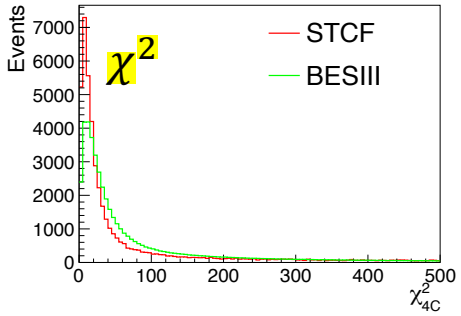
BESIII & STCF comparisons

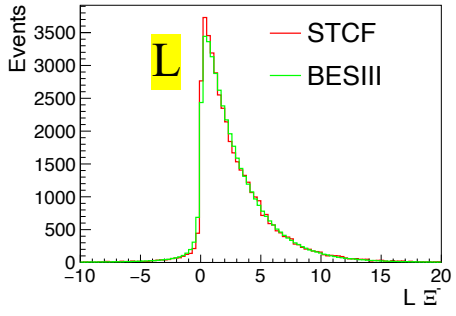
In reconstruction level: check $\theta, cos\theta, Mom$

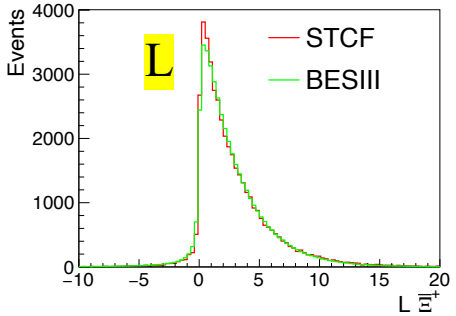


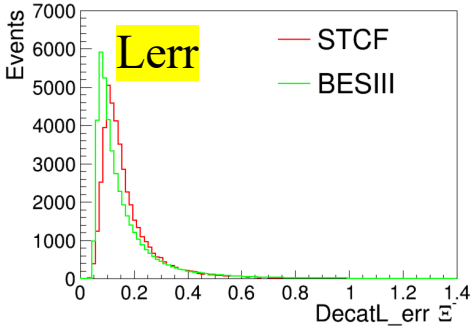
BESIII & STCF comparisons

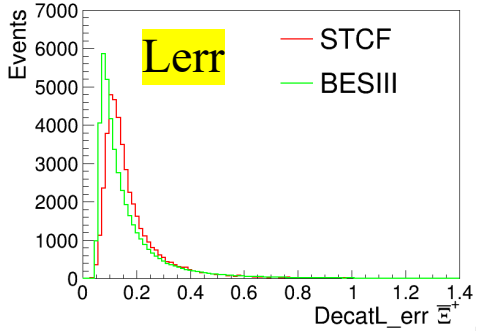
Check χ^2, L, Lerr, L/Lerr, Mass

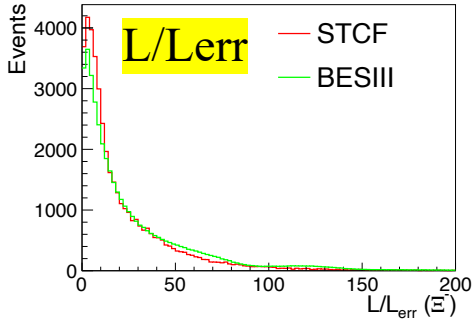


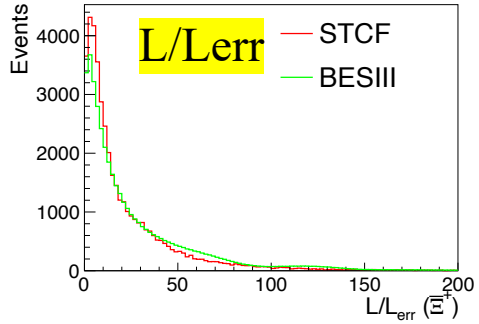


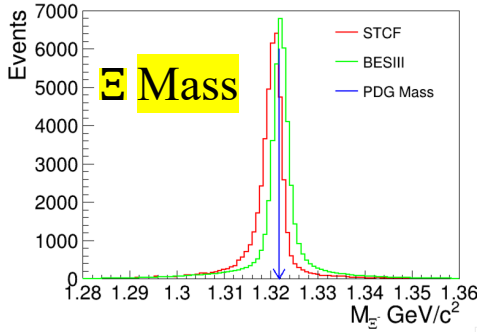


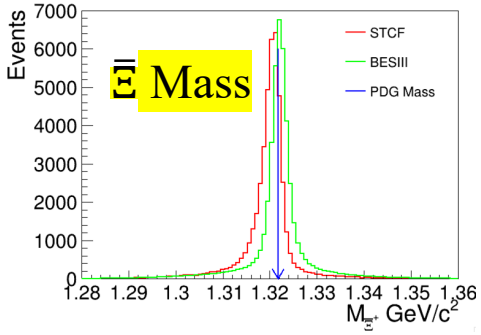


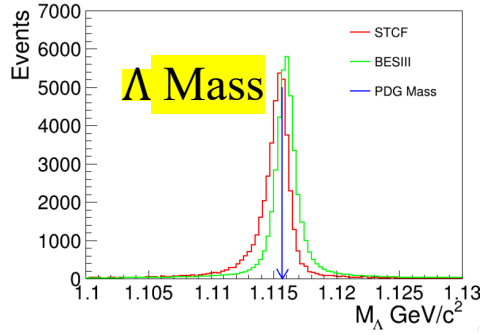


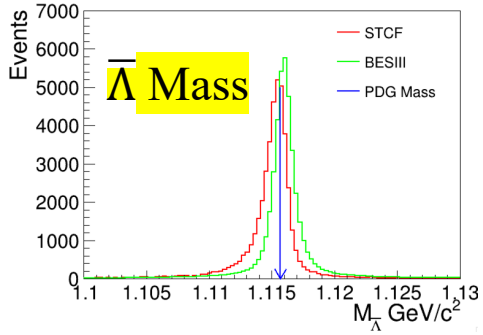






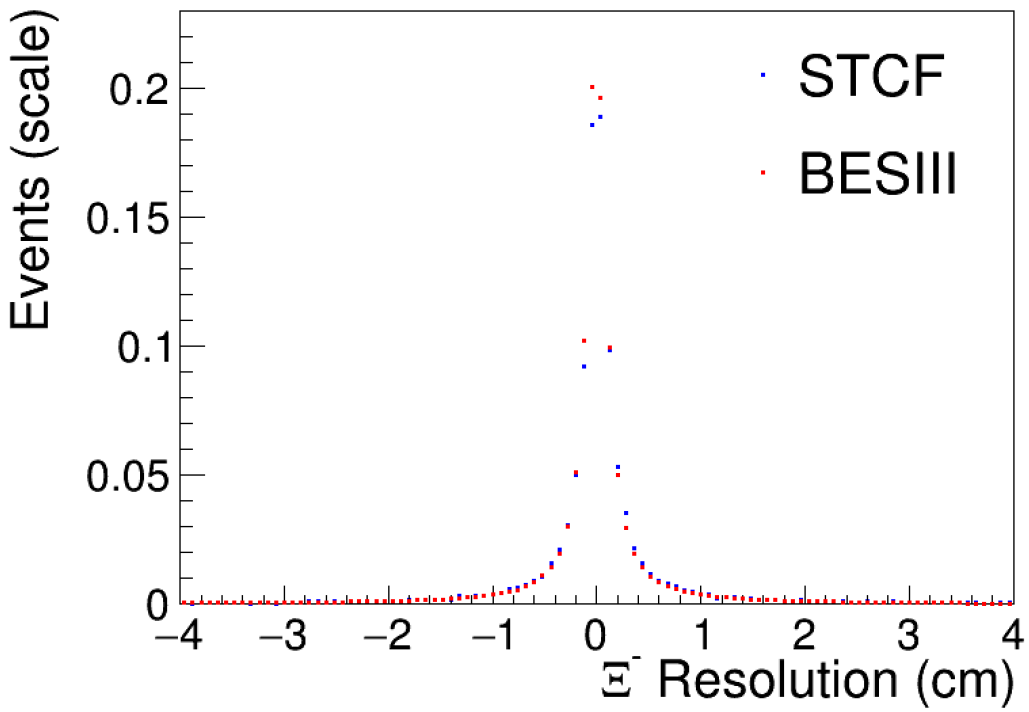


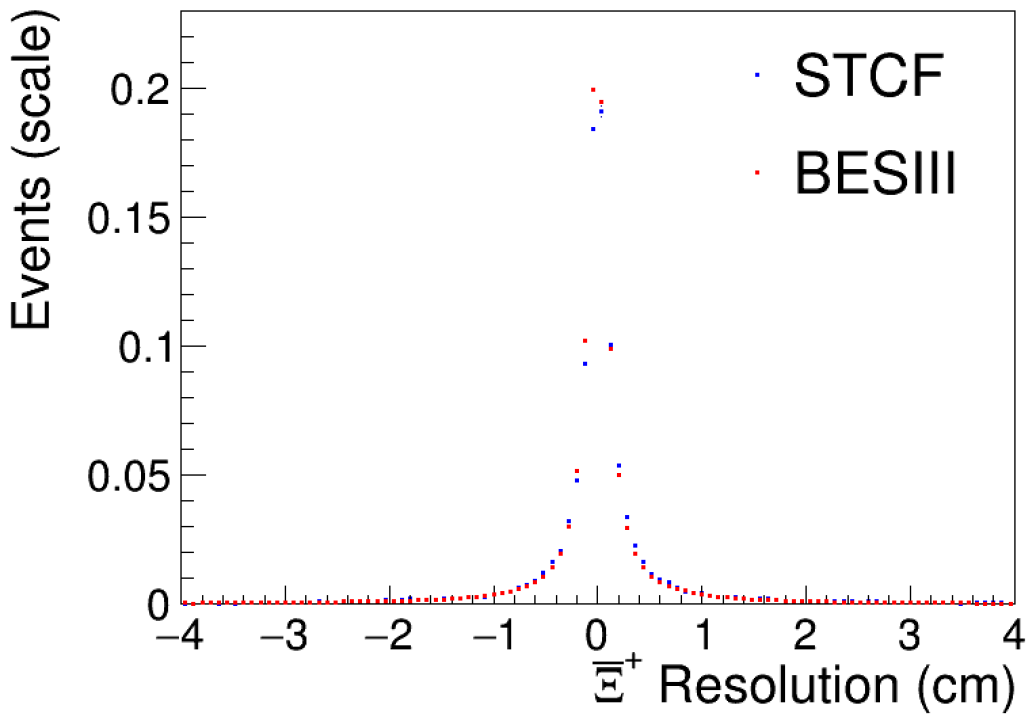




BESIII & STCF comparisons

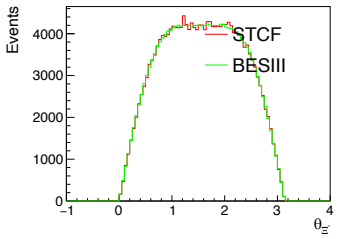
Check resolution of decay length

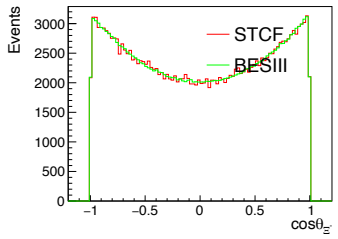


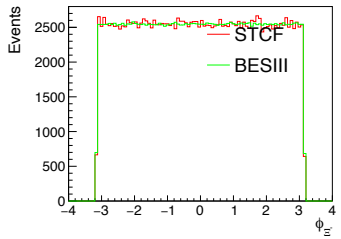


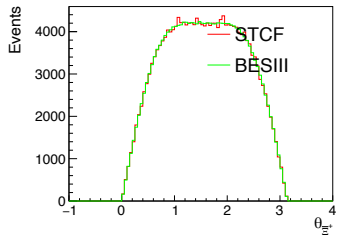
BESIII & STCF comparisons

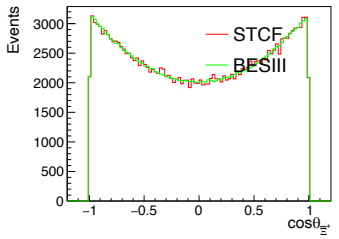
Check Helicity angles in truth level:

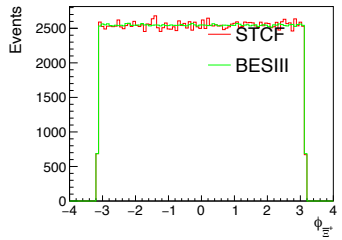


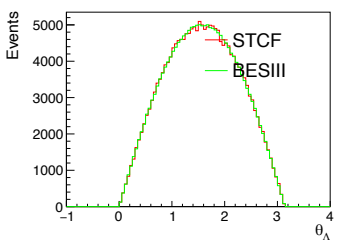


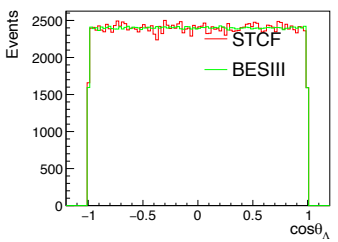


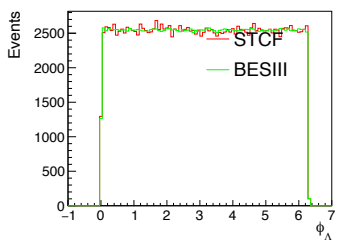


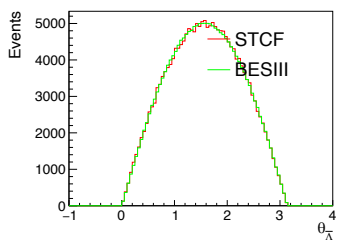


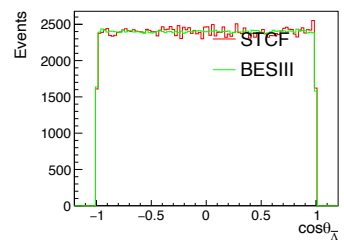


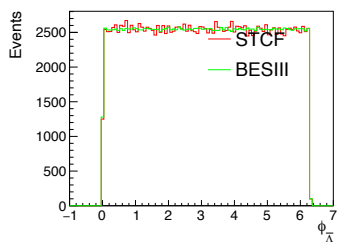


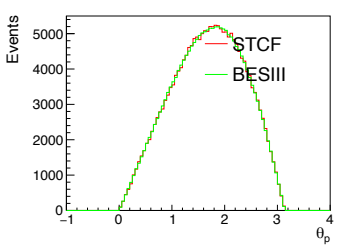


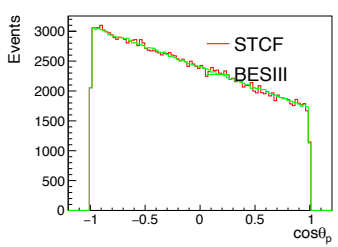


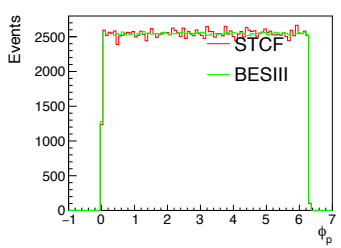


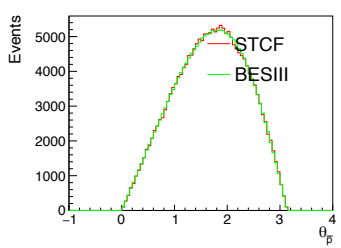


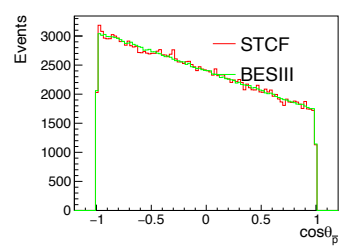


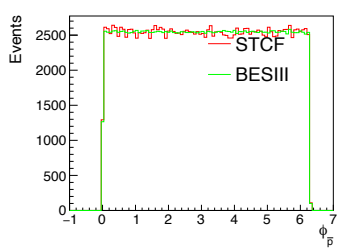






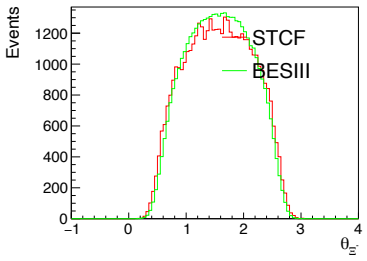


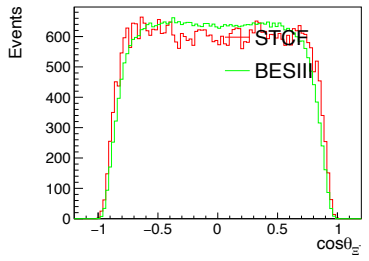


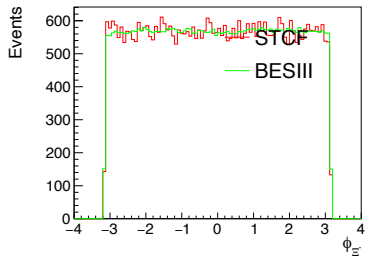


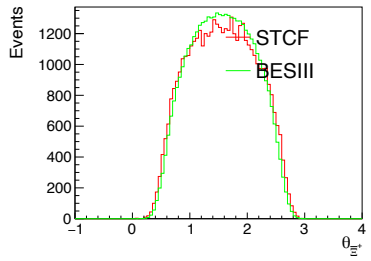
BESIII & STCF comparisons

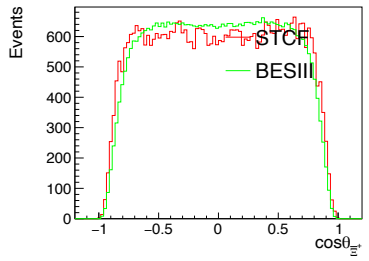
Check Helicity angles in reconstruction level:

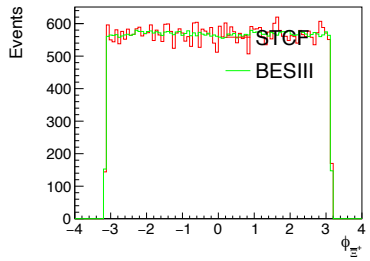


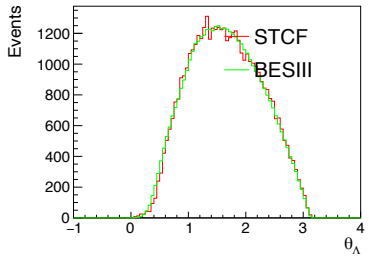


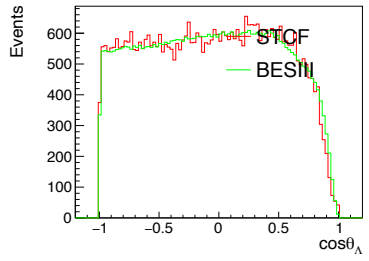


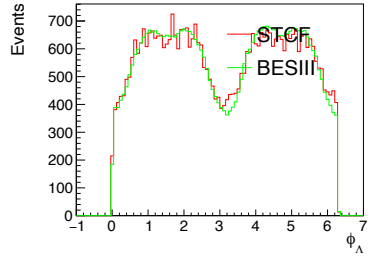


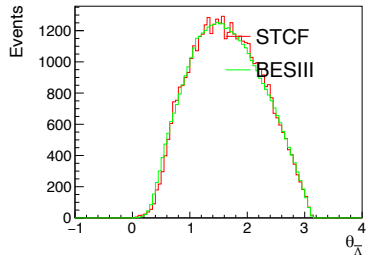


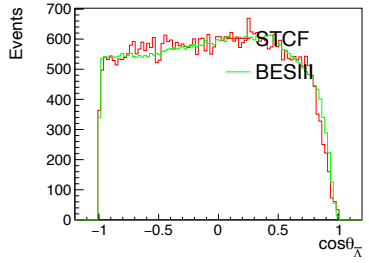


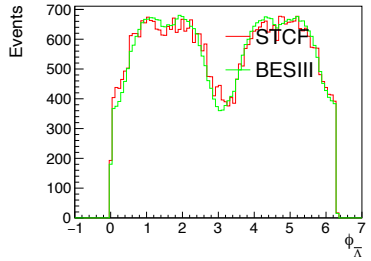


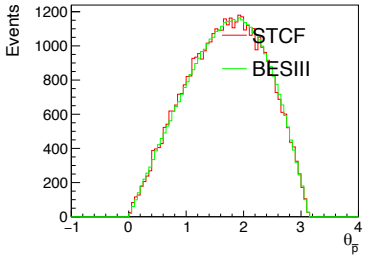


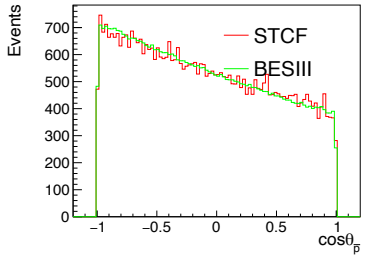


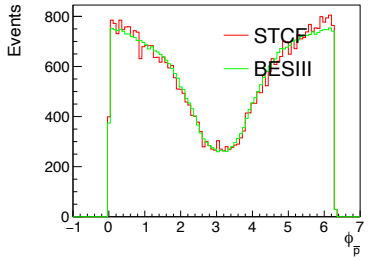


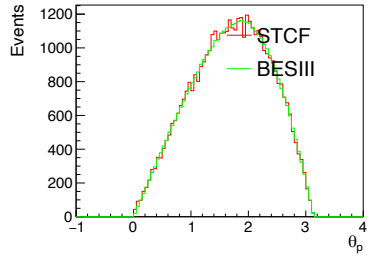


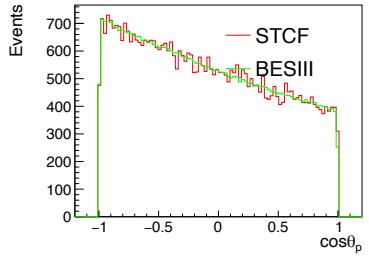


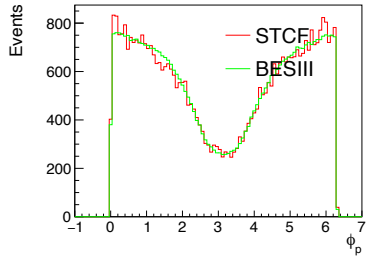












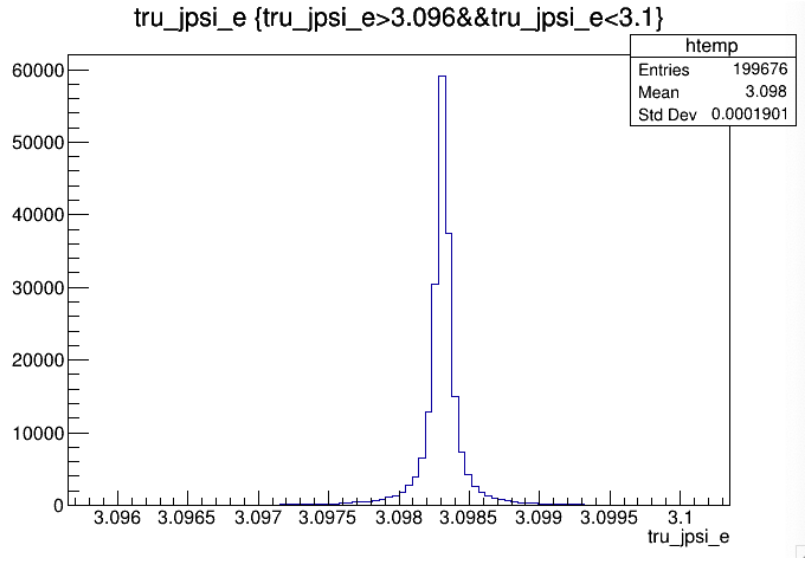
Summary

- The process $e^+e^- \to J/\psi \to \Xi^-\ \bar{\Xi}^+$ has been generated using the OSCAR software. And the signal events have been preliminarily selected.
- The signal selection efficiency has improved by ~16% compared to BESIII.

- The discrepancy between BESIII and STCF：
  - Selection efficiency (charged track)
  - Ξ momentum
  - Invariant mass of Ξ、Λ
  - Decay length error of Ξ

Backup

- genTool.property("Boost").set(True)



Since e^+e^- isn't a complete head-to-head collision, the cross angle needs to be considered in the simulation, from the CMS boost to the Lab system.

- genTool.property("Boost").set(False)