Measurements of the branching fraction for $\Xi^- \to \Lambda e^- \nu$

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Outline

- Motivation
- Analysis strategy
- Data sets
- Summary

Double Tag Method

Double tag method can reduce several terms of systematic uncertainty.

- Tag Mode: $\bar{\Xi}^+ \to \bar{\Lambda}\,\pi^+, \bar{\Lambda} \to \bar{p}^-\pi^+$
- Signal Mode: $\Xi^- \to \Lambda\, e^-\,\bar{\nu}_e, \Lambda \to p^+\pi^-$

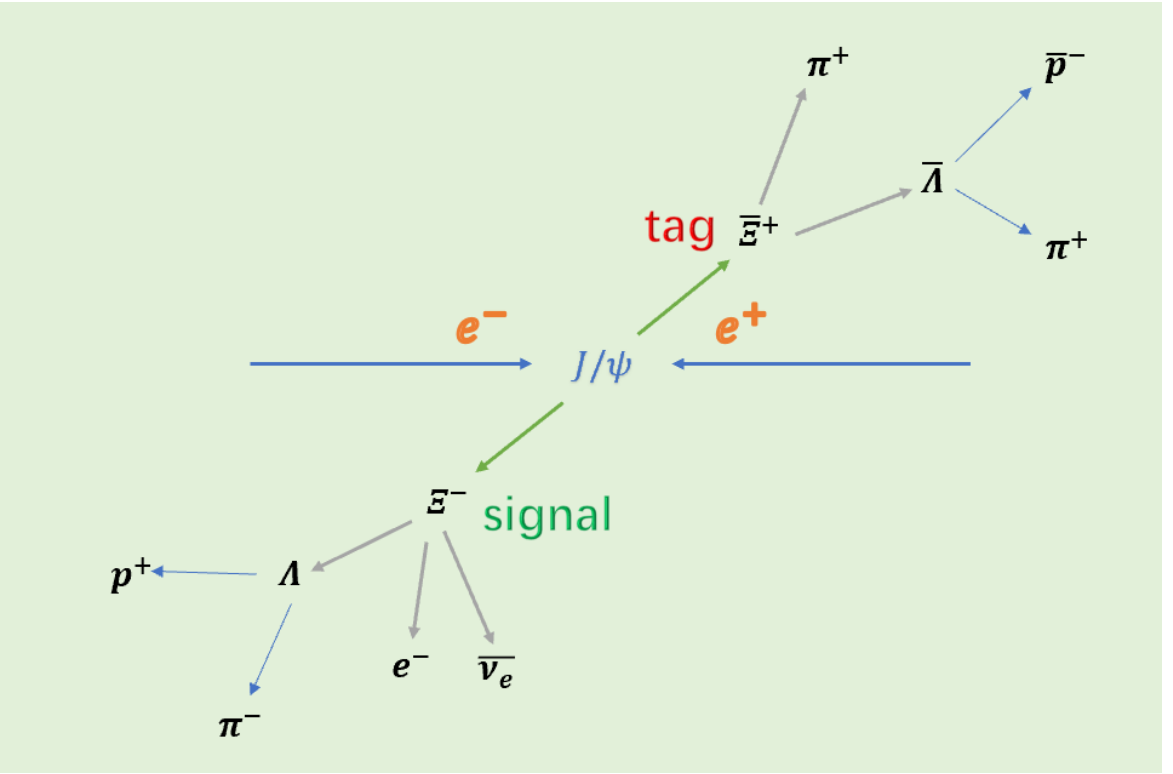
Yield of each side:

- $N_{st} = N_{J/\psi} \cdot Br_{J/\psi \to \bar{\Xi}^+\Xi^-} \cdot Br_{\bar{\Xi}^+ \to \bar{\Lambda}\pi^+} \cdot Br_{\bar{\Lambda} \to p^+\pi^-} \cdot \epsilon_{st}$
- $N_{dt} = N_{J/\psi} \cdot Br_{J/\psi \to \bar{\Xi}^+\Xi^-} \cdot Br_{\bar{\Xi}^+ \to \bar{\Lambda}\pi^+} \cdot Br_{\bar{\Lambda} \to p^+\pi^-} \cdot Br_{\Xi^- \to \Lambda\, e^-\,\bar{\nu}_e} \cdot Br_{\Lambda \to \bar{p}^-\pi^+} \cdot \epsilon_{dt}$

$$\boldsymbol{Br_{\Xi^- \to \Lambda\, e^-\,\bar{\nu}_e} = \frac{N_{dt} \cdot \epsilon_{st}}{N_{st} \cdot Br_{\Lambda \to \bar{p}^-\pi^+} \cdot \epsilon_{dt}}}$$

Ξ^- DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\Lambda\pi^-$	(99.887 ± 0.035) %	
Γ_2	$\Sigma^-\gamma$	(1.27 ± 0.23) × 10^{-4}	
Γ_3	$\Lambda e^-\bar{\nu}_e$	(5.63 ± 0.31) × 10^{-4}	
Γ_4	$\Lambda\mu^-\bar{\nu}_\mu$	(3.5 $^{+3.5}_{-2.2}$) × 10^{-4}	
Γ_5	$\Sigma^0 e^-\bar{\nu}_e$	(8.7 ± 1.7) × 10^{-5}	
Γ_6	$\Sigma^0\mu^-\bar{\nu}_\mu$	< 8 × 10^{-4}	90%
Γ_7	$\Xi^0 e^-\bar{\nu}_e$	< 2.3 × 10^{-3}	90%



Data sets

BOSS version: 7.0.5

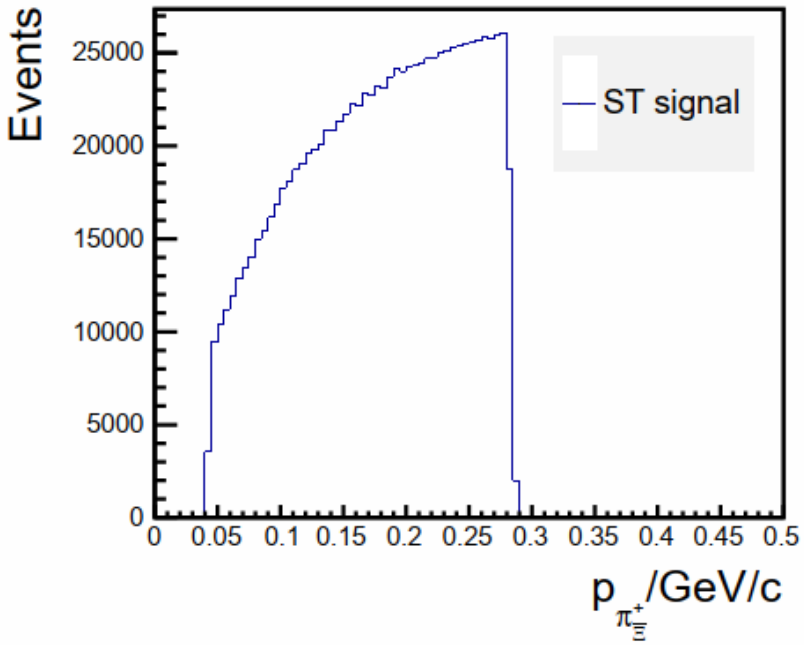
SignalMC: 0.5M $J/\psi \to \bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Xi^- \to \Lambda\, e^-\, \bar{\nu}_e, \bar{\Lambda} \to \bar{p}^-\pi^+, \Lambda \to p^+\pi^-$ PHSP

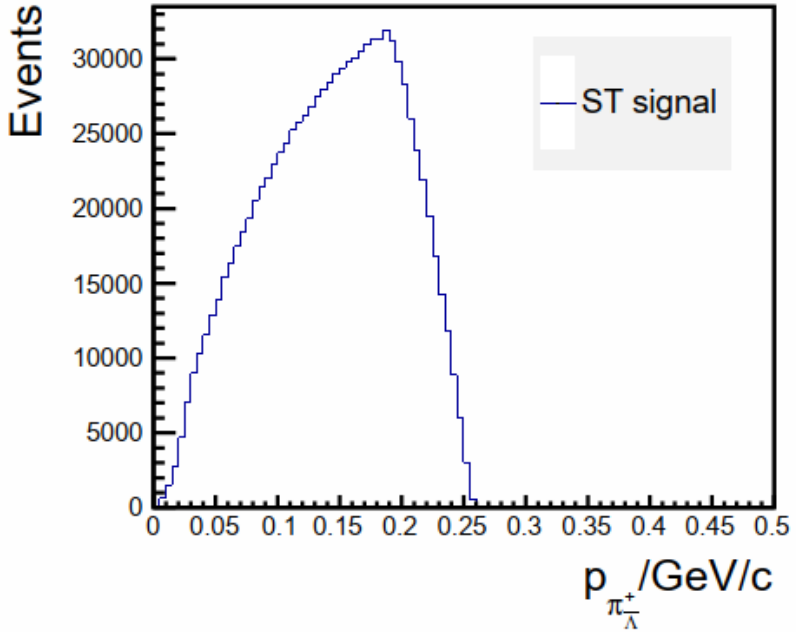
BackgroundMC: 14M $J/\psi \to \bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Xi^- \to \Lambda\,\pi^-, \bar{\Lambda} \to \bar{p}^-\pi^+, \Lambda \to p^+\pi^-$ mDIY

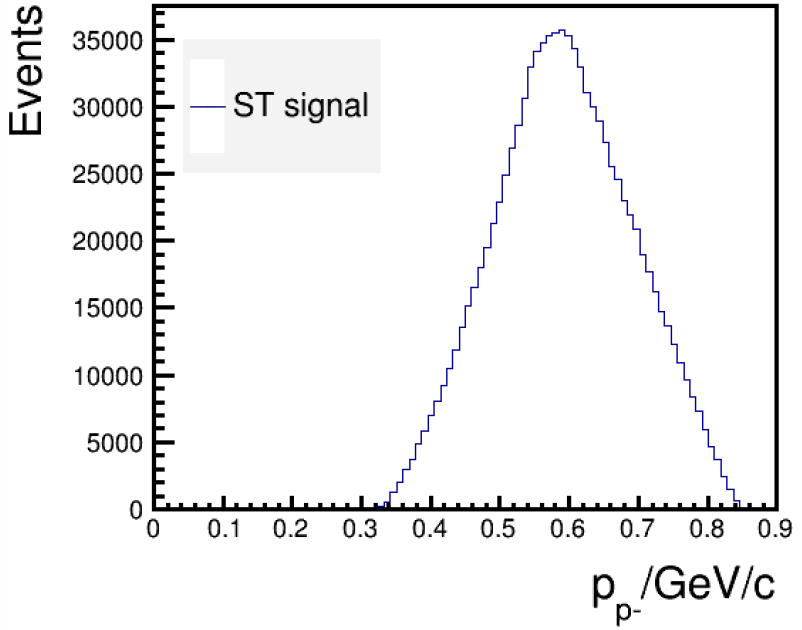
InclusiveMC: 10B J/ψ inclusive mc

Data: 10B J/ψ data

ST signal MC truth information







ST signal : $J/\psi \rightarrow \bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \rightarrow \bar{\Lambda}\pi^+, \bar{\Lambda} \rightarrow \bar{p}^-\pi^+, \Xi^- \rightarrow anything.$

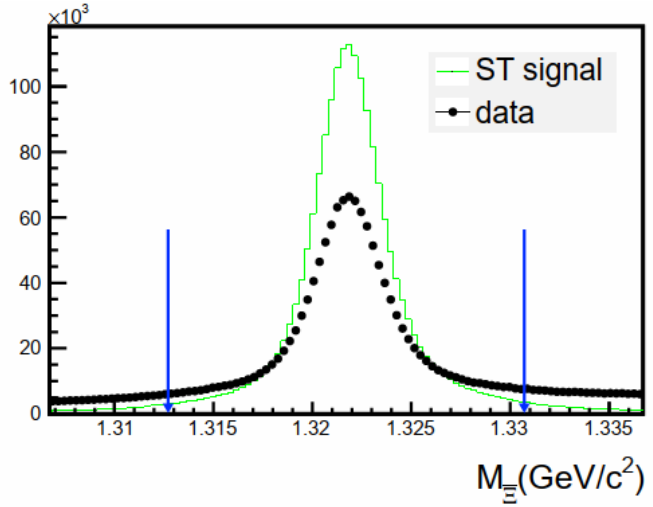
ST Event Selection

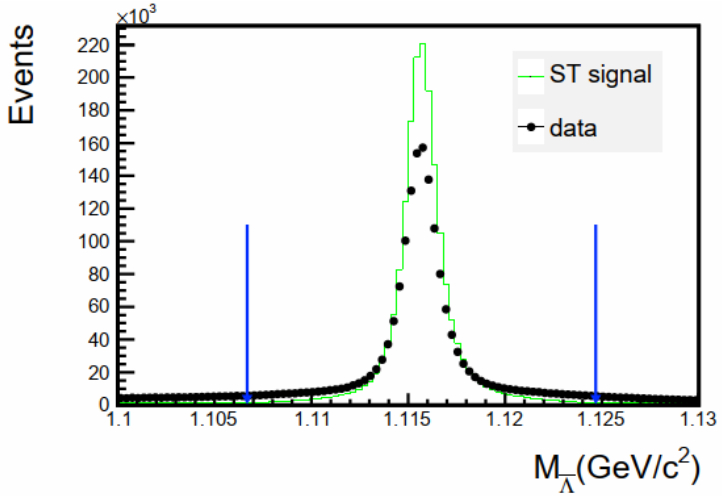
- **Charged tracks**
  - ✓ No Vertex requirement; $|\cos\theta| < 0.93$; $N_{charge^+} \geq 2$; $N_{charge^-} \geq 1$;

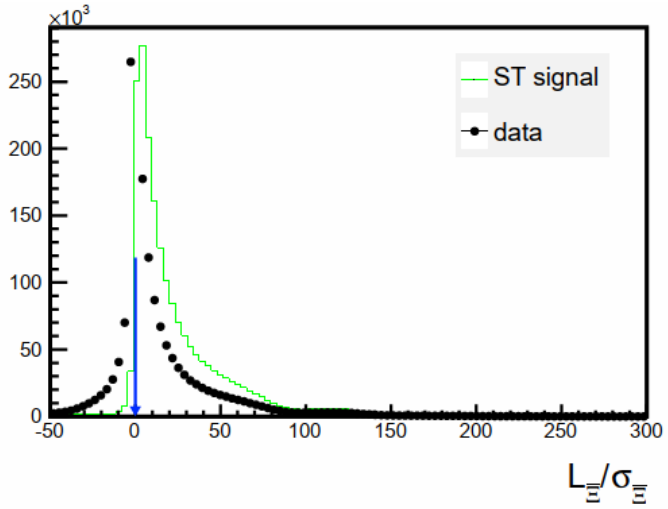
- **Particle ID**
  - ✓ Proton: p>0.32 GeV/c; $N_{\bar{p}^-} \geq 1$
  - ✓ Pion: p<0.30 GeV/c; $N_{\pi^+} \geq 2$

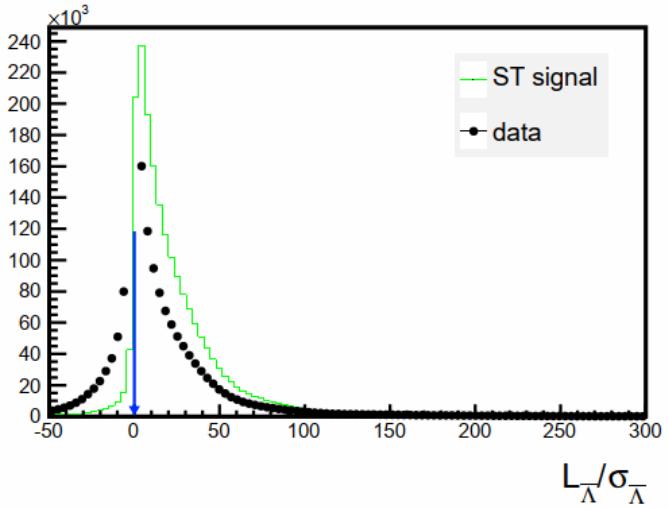
- **Vertex fit for $\bar{\Lambda}$, $\bar{\Xi}^+$**
  - ✓ Primary vertex fit were applied to $\bar{p}^-\pi^+$ for $\bar{\Lambda}$, $\bar{\Lambda}\pi^+$ for $\bar{\Xi}^+$. Secondary vertex fit were applied between $\bar{\Lambda}$ and $\bar{\Xi}^+$, $\bar{\Xi}^+$ and initial vertex. Loop all the pairs, select combination by minimizing
    $\chi^2 = \left(M(\bar{p}^-\pi^+) - M(\Lambda_{PDG})\right)^2 + \left(M(\bar{\Lambda}_{\bar{p}\pi^+}\pi^+) - M(\Xi_{PDG})\right)^2$
  - ✓ $\frac{decaylength_{\bar{\Lambda}}}{decaylengtherr_{\bar{\Lambda}}} > 0$ && $\frac{decaylength_{\bar{\Xi}}}{decaylengtherr_{\bar{\Xi}}} > 0$
  - ✓ $|M_{\bar{\Xi}} - 1.32171| < 0.009$ && $|M_{\bar{\Lambda}} - 1.115683| < 0.009$

Event Selection

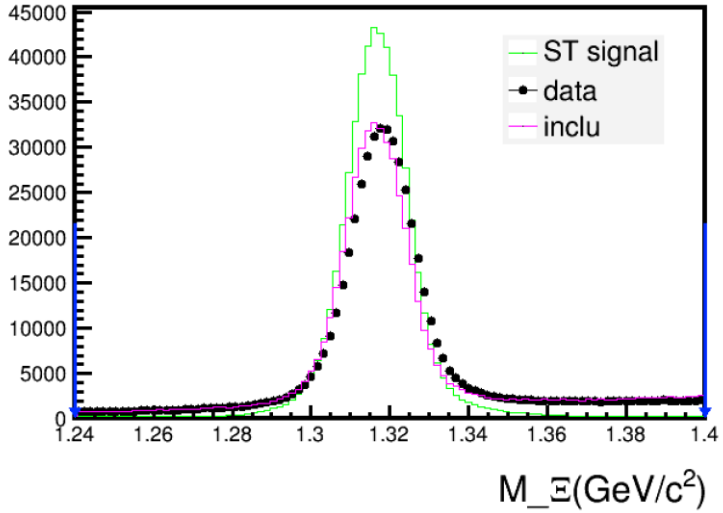


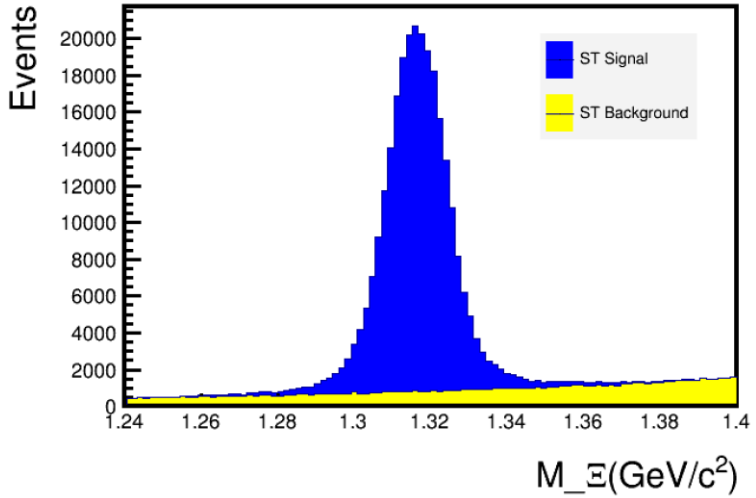


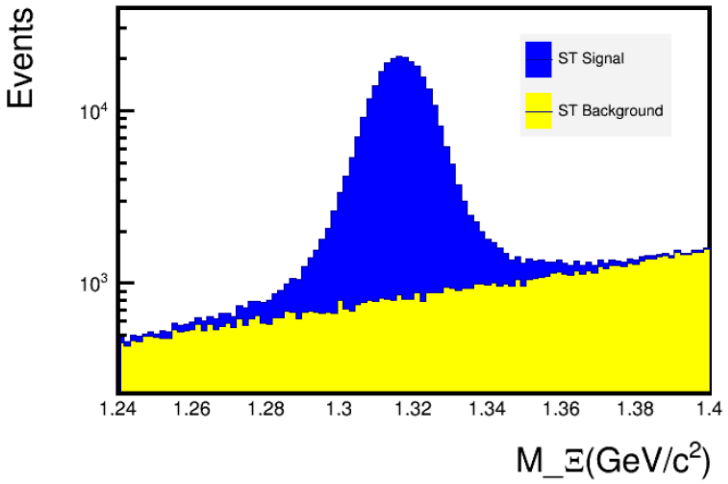




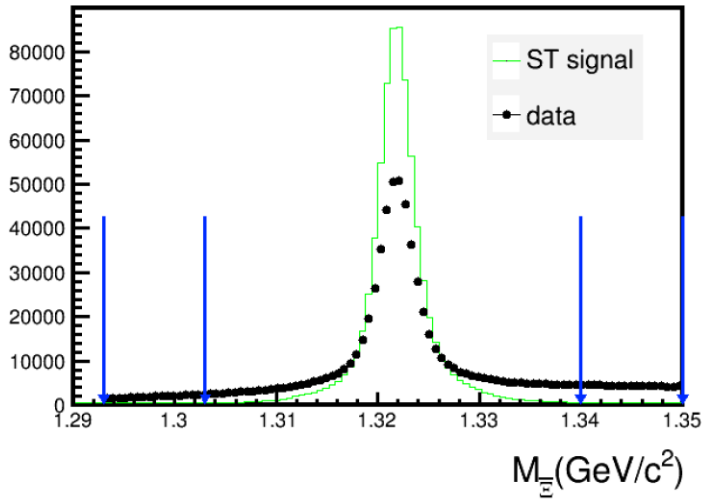
Event Selection

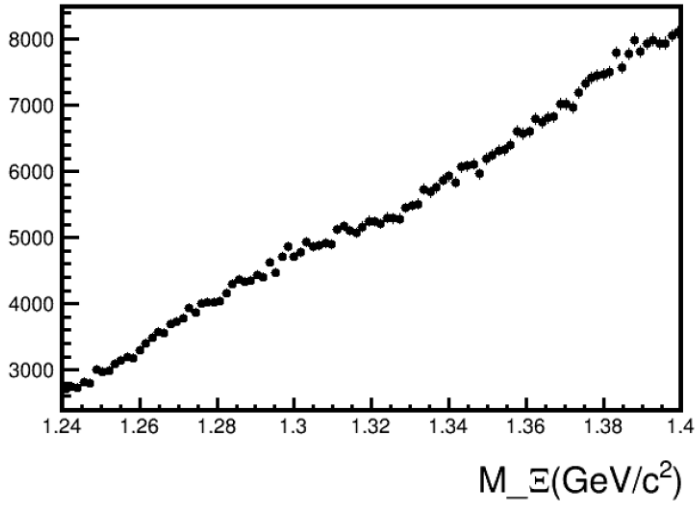






✓ $1.24 < M_{\Xi} < 1.4$

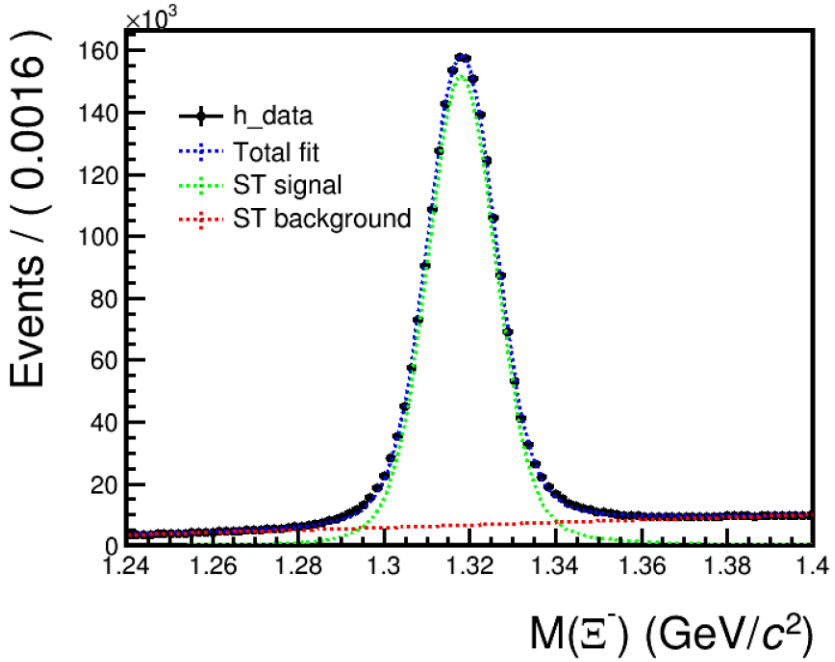




Yield Extraction Strategy

➢ Single tag yield

- ✓ 1Million background mc +0.56 Million J/ψ → $\bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \bar{\Lambda} \to \bar{p}^-\pi^+, \Xi^- \to \Lambda\pi^-, \Lambda \to n\pi^0$, signal shape
- ✓ Signal Shape⊗*Gaussian* + 1st order Chebychev polynomial
- ✓ 10B J/ψ data
- ✓ Recoil Ξ^- mass : ecms - $\bar{\Xi}^+$



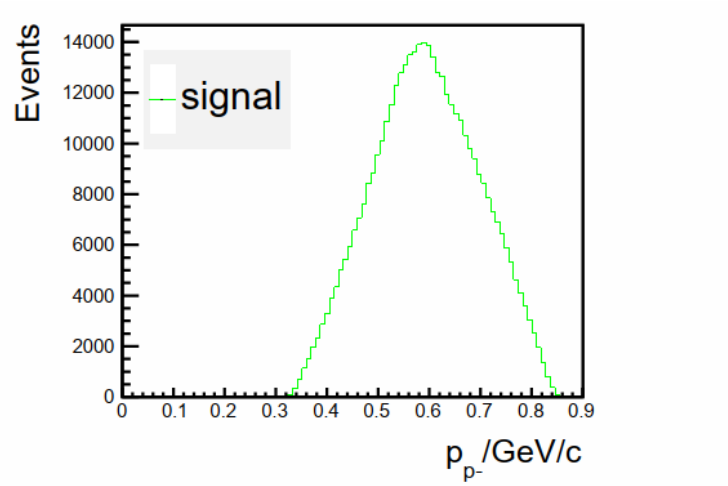
$\Xi^- \to \Lambda\pi^-$ $(99.887 \pm 0.035)\%$

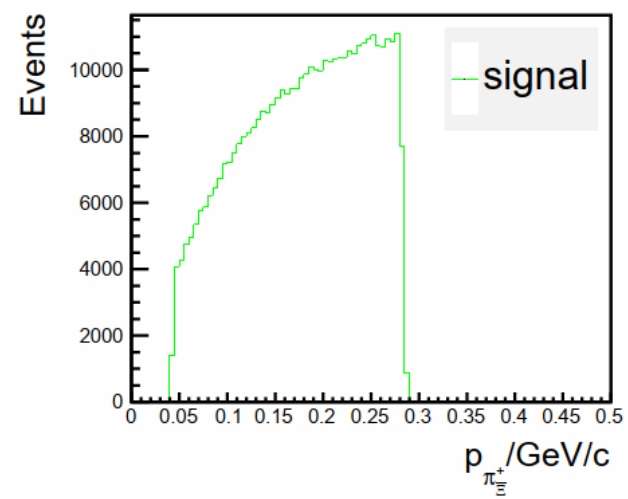
$\Lambda \to p^+\pi^-$ $(63.9 \pm 0.5)\%$

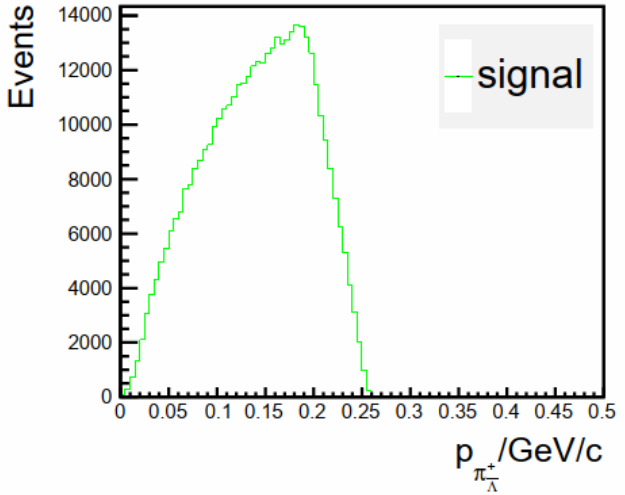
$\Lambda \to n\pi^0$ $(35.8 \pm 0.5)\%$

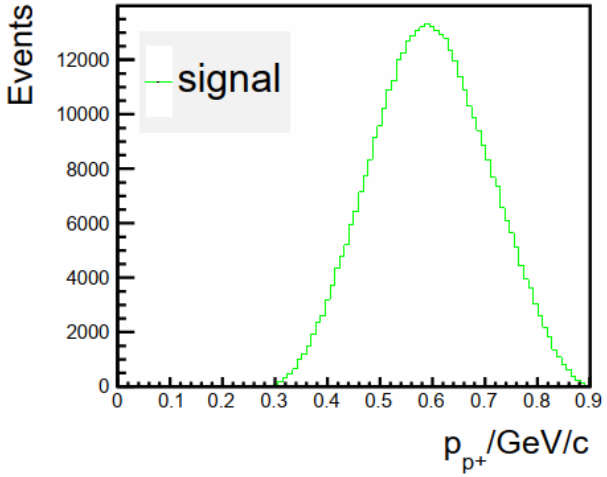
Modes	$J/\psi \to \Xi^-\bar{\Xi}^+, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \bar{\Lambda} \to p^-\pi^+, \Xi^- \to anything$
Yield	2024560 ± 1578
ST signal efficiency(ε_{ST})	27.66%

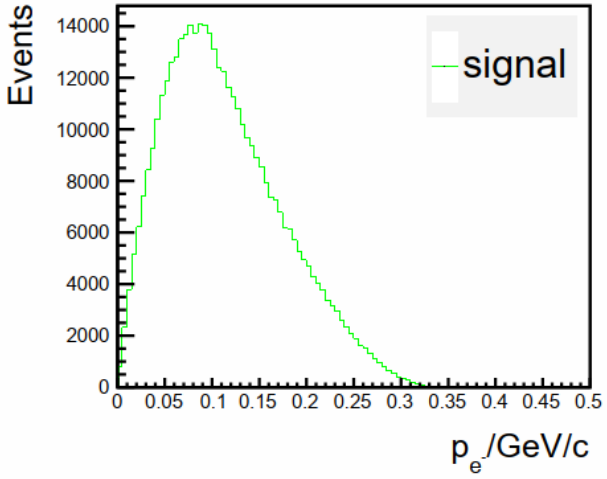
DT signal MC truth information

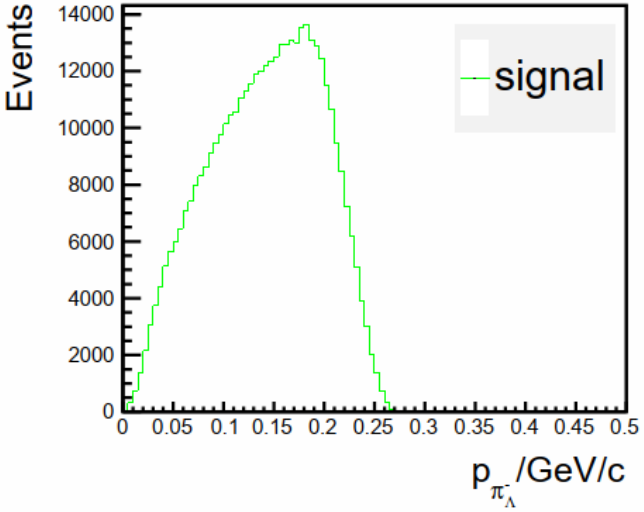












Event Selection

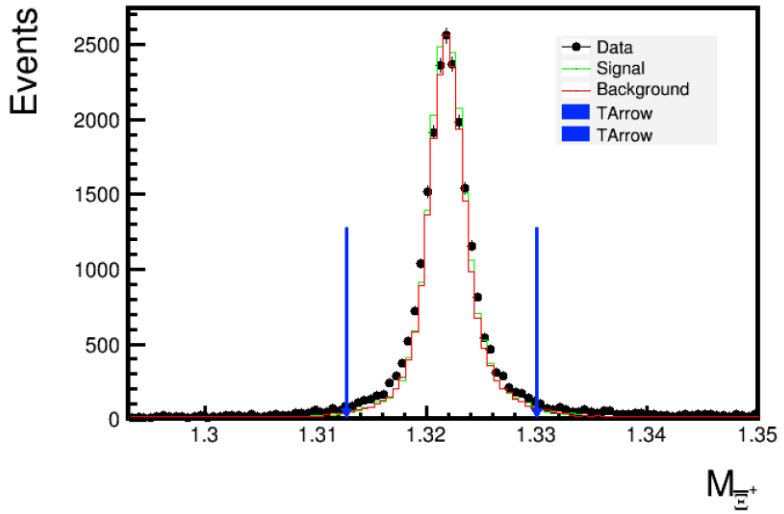
- **Particle ID**
  - ✓ Proton: p>0.32 GeV/c; $N_{p^+} \geq 1$
  - ✓ Pion or electron: p<0.30 GeV/c; N ≥ 2
  - ✓ Electron: $\frac{Prob\_e}{Prob_k+Prob_{pi}+Prob\_e}$>0.8 ; ie.size()>=1, ipim.size()>=1;
- **Vertex fit for** Λ, Ξ^-
  - ✓ Primary vertex fit were applied to $p^+\pi^-$ for Λ, Λe^- for Ξ^-. Secondary vertex fit were applied between Λ and Ξ^-. Loop all the pairs, select combination by minimizing $\chi^2 = chisq_{p\pi^-} + chisq_{\Lambda e^-} + chisq_{\Lambda\to\Xi^-}$
  - ✓ $|M_\Lambda - 1.115683| < 0.009$ && $\left|M_{\Xi_{recoil}} - 1.31639\right| < 0.023$ $P_{\Xi_{recoil}} = ecms - P_{\bar{\Xi}}$
  - ✓ $\frac{decaylength_\Lambda}{decaylengtherr_\Lambda} > 0$

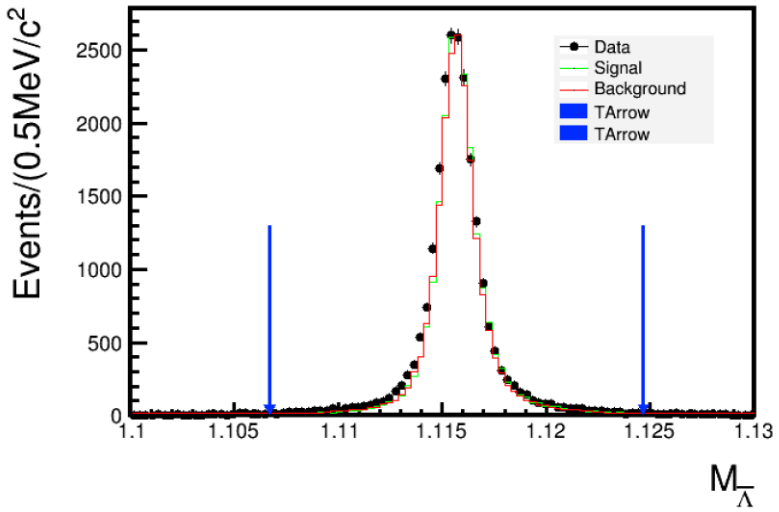
Background analysis

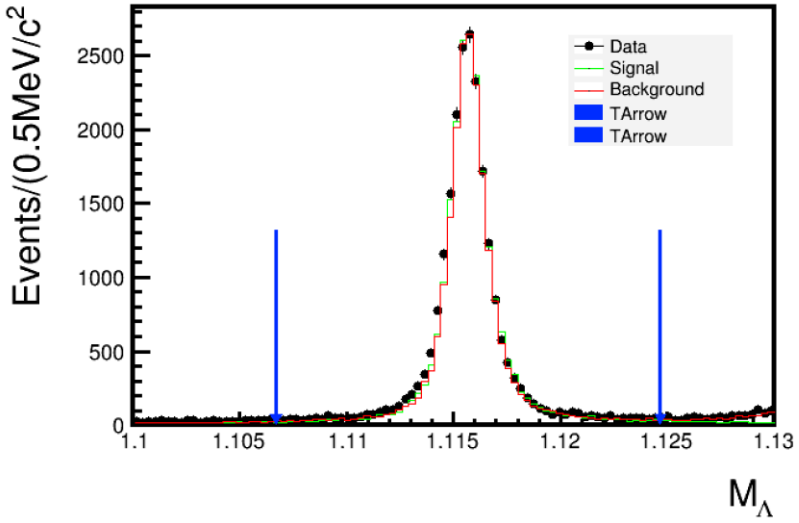
- 1311 Million inclusive mc is used to find possible background process. In the below table, it is clear to see the dominant background is $J/\psi \to \bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Xi^- \to \Lambda\pi^-, \bar{\Lambda} \to \bar{p}^-\pi^+, \Lambda \to p^+\pi^-$.

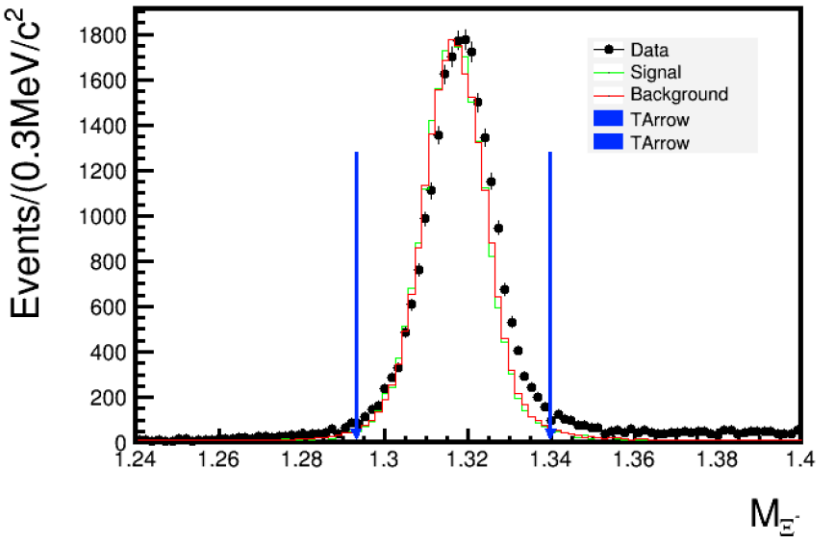
	decay channels	Event number left
1	$J/\psi \to \Xi^-\bar{\Xi}^+, \Xi^- \to \Lambda\pi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Lambda \to p^+\pi^-, \bar{\Lambda} \to p^-\pi^+$	3471
2	$J/\psi \to \pi^+\pi^-\Lambda\bar{\Lambda}, \bar{\Lambda} \to \bar{p}^-\pi^+, \Lambda \to p^+\pi^-$	27
3	$J/\psi \to \eta_c\gamma, \eta_c \to \bar{\Xi}^+\Xi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \bar{\Lambda} \to \bar{p}^-\pi^+, \Xi^- \to \Lambda\pi^-, \Lambda \to p^+\pi^-$	24
4	$J/\psi \to \Xi^-\bar{\Xi}^+, \Xi^- \to \Lambda\pi^-\gamma, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Lambda \to p^+\pi^-, \bar{\Lambda} \to p^-\pi^+$	12
5	$J/\psi \to \Xi^-\bar{\Xi}^+\gamma, \Xi^- \to \Lambda\pi^-, \bar{\Xi}^+ \to \bar{\Lambda}\pi^+, \Lambda \to p^+\pi^-, \bar{\Lambda} \to p^-\pi^+$	7
6	other processes	63

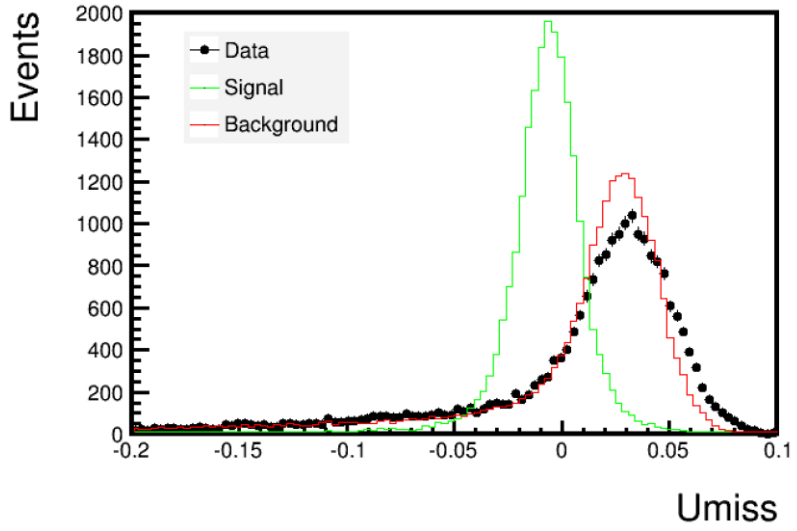
Double tag analysis





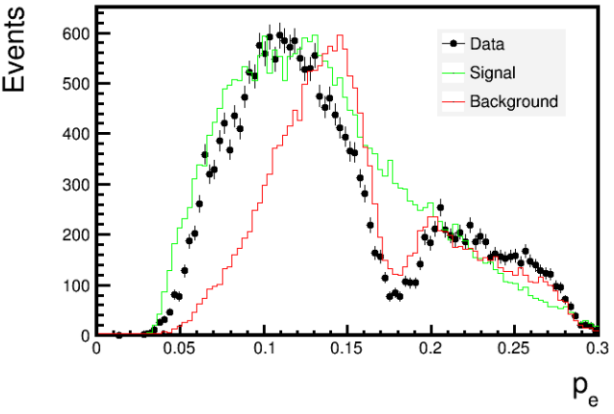


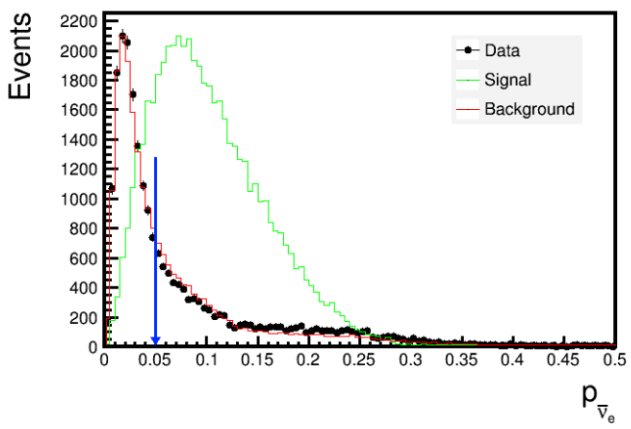


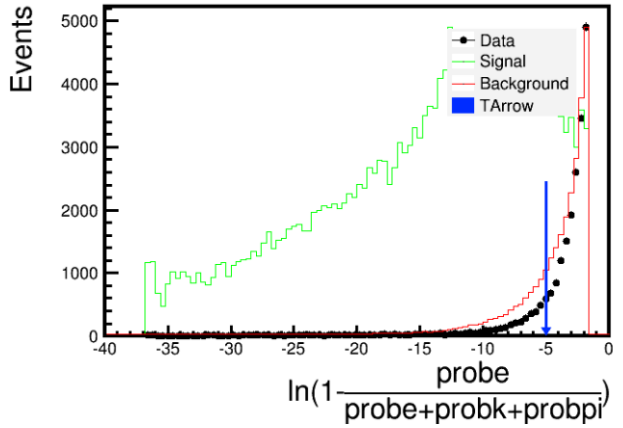


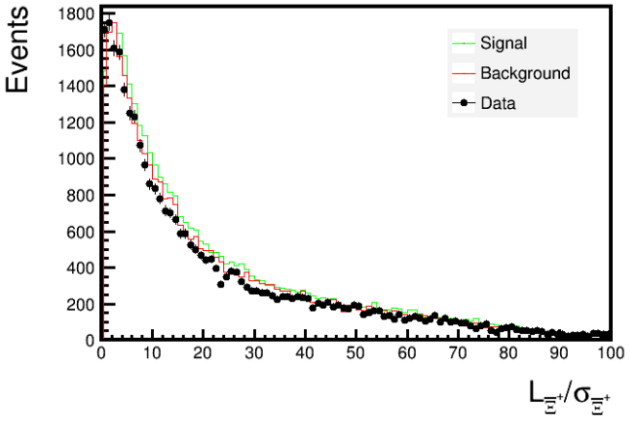
$$Umiss = E_{\bar{\nu}_e} - p_{\bar{\nu}_e}$$

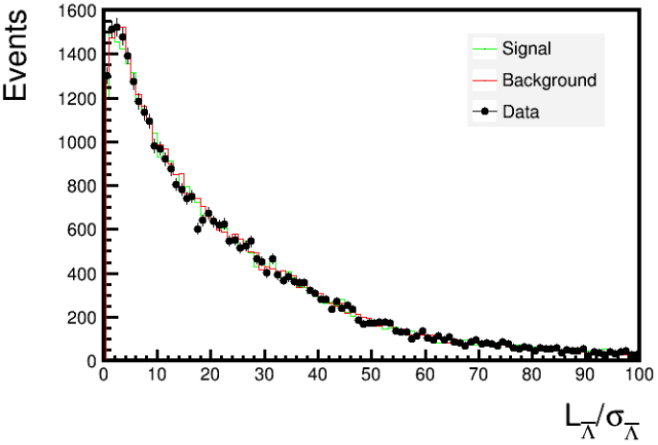
Background veto

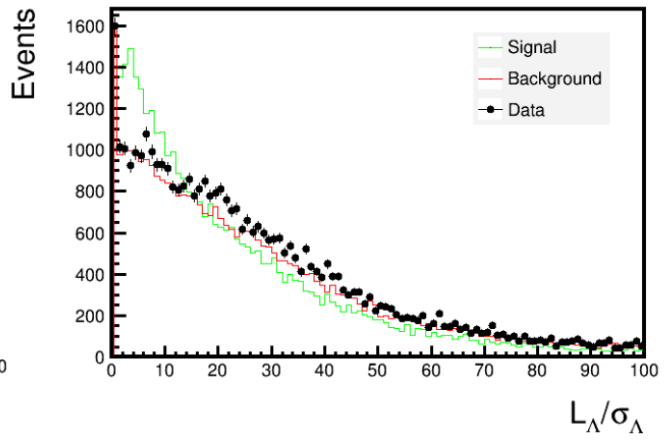


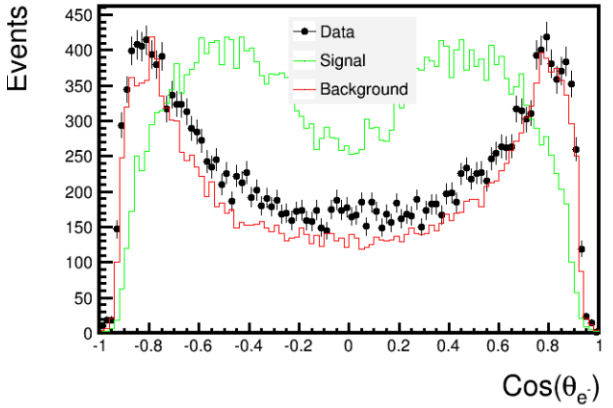


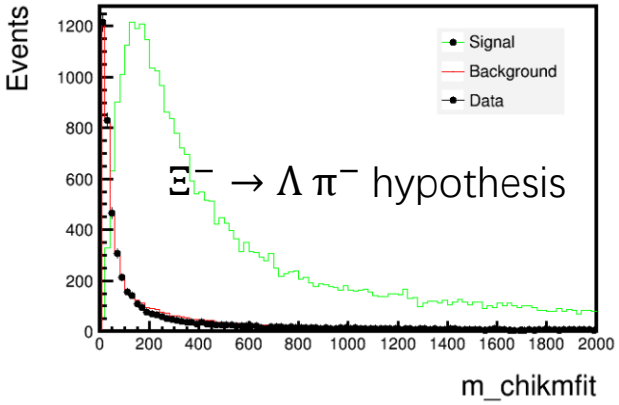










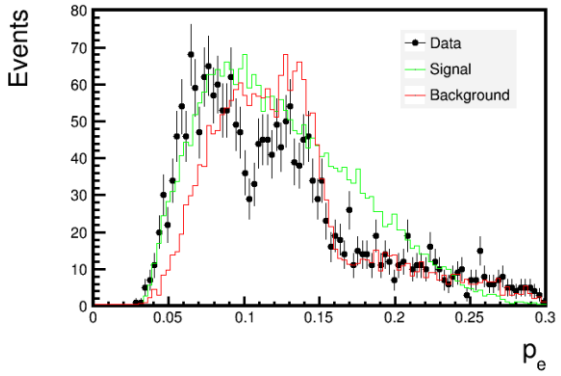


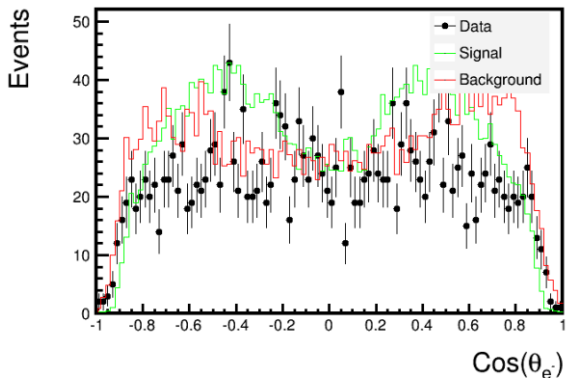
Background veto

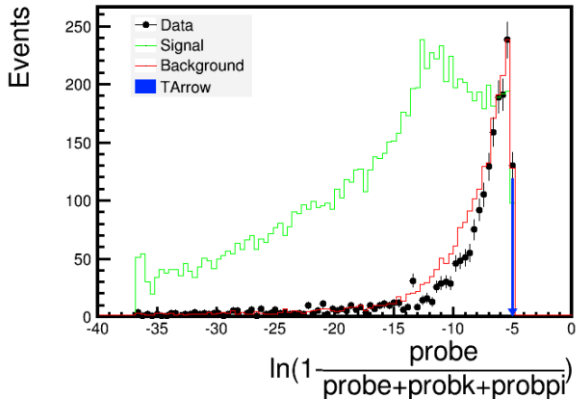
- $\ln\left(1-\frac{probe}{probe+probpi+probk}\right)<-5 \quad or \quad \frac{probe}{probe+probpi+probk}>0.993$
- $p_\nu > 0.05$
- Signal efficiency : 0.057
- Background efficiency : 0.000651
- 0.057/0.000651=88

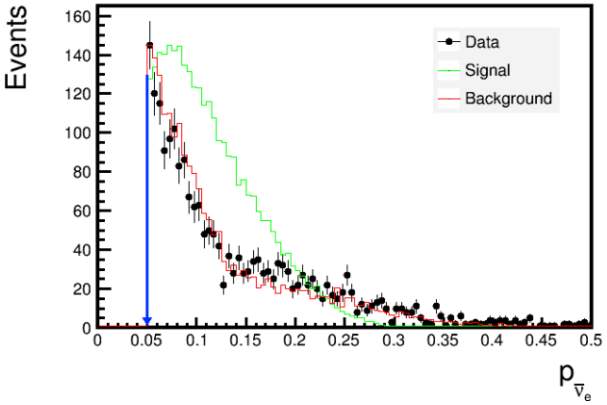
Source	Data	Signal	Background
Total	10 billion	500000	14 million
After DT Vertex fit,PID	5766447	66563	222201
Decaylenth > 0,mass window	22720	37899	55682
$ln(1-\frac{probElectron}{probElectron+probPion+probKaon})$ < -5	5290	34493	20150
$p_{\bar{\nu}_e} > 0.05$	2214	28661	9118

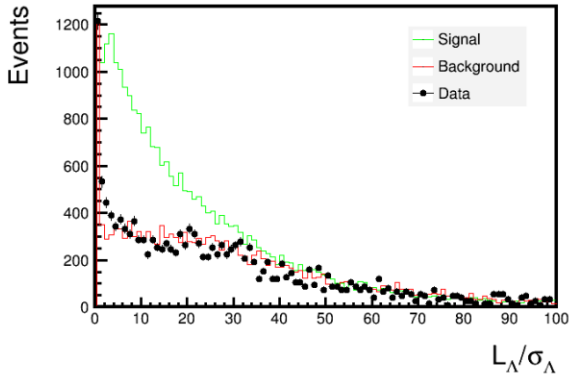
Background veto

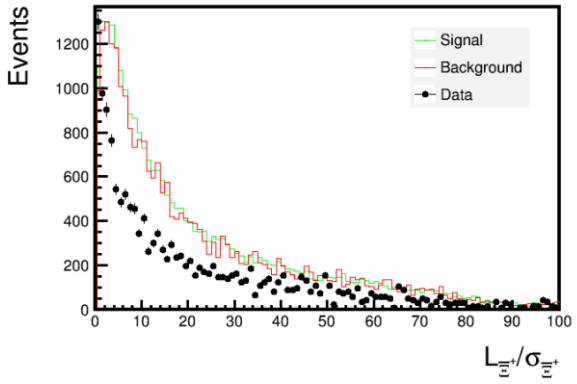


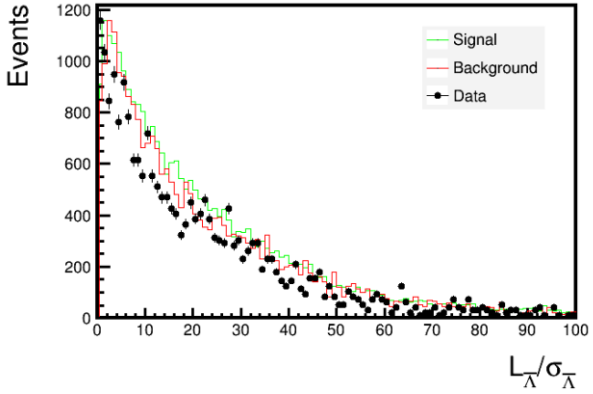


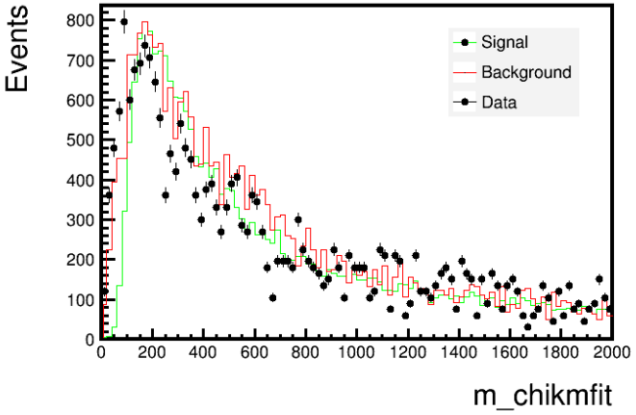




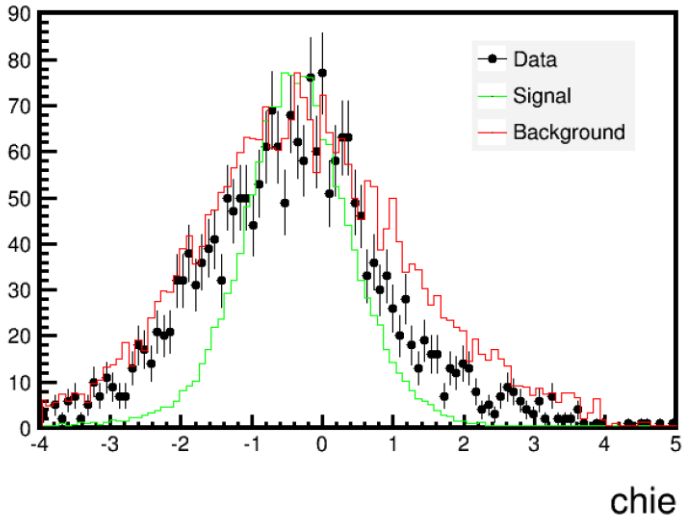


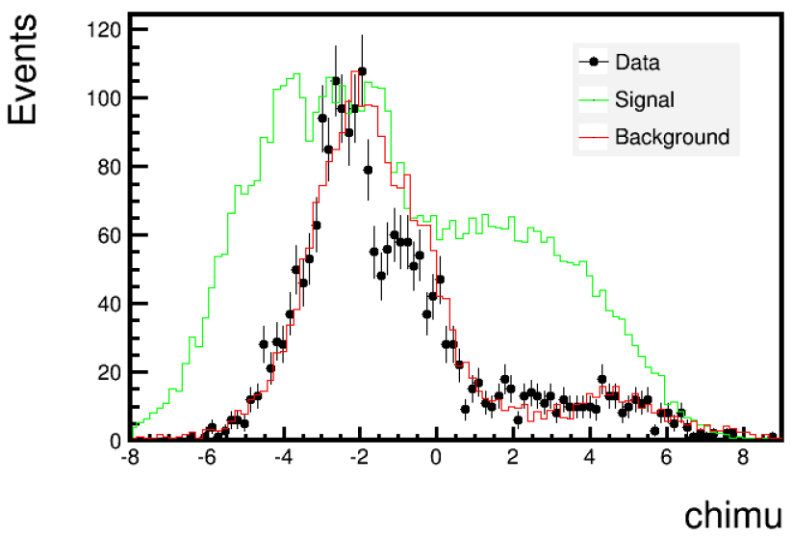


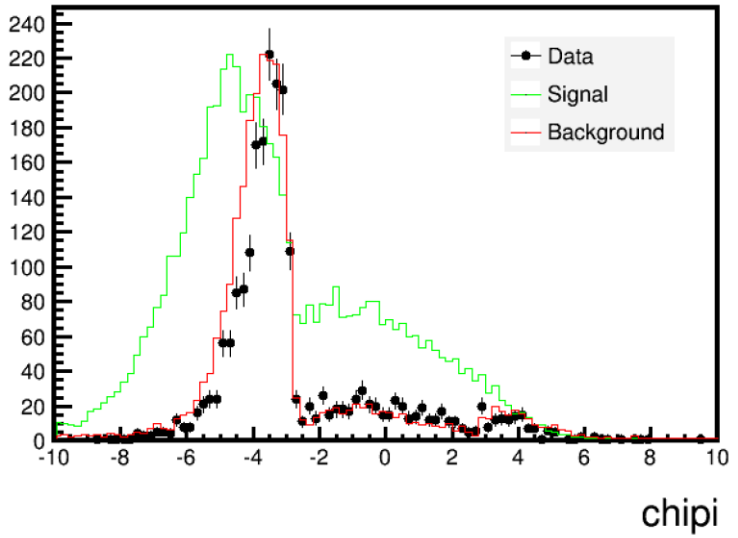


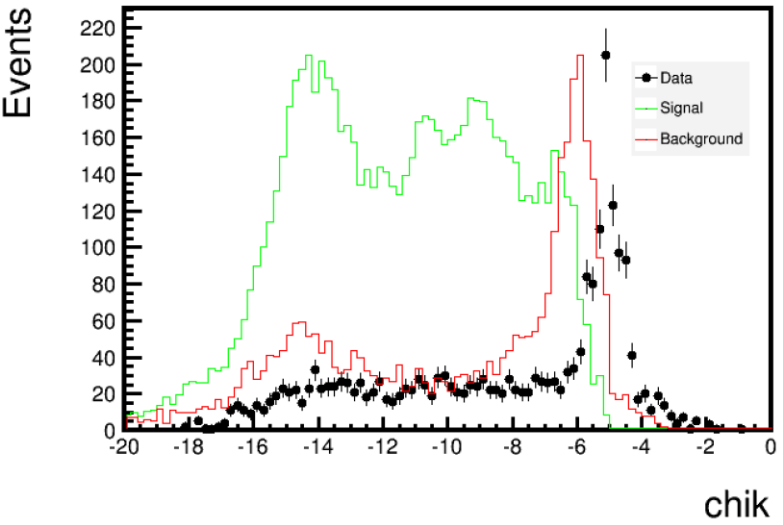


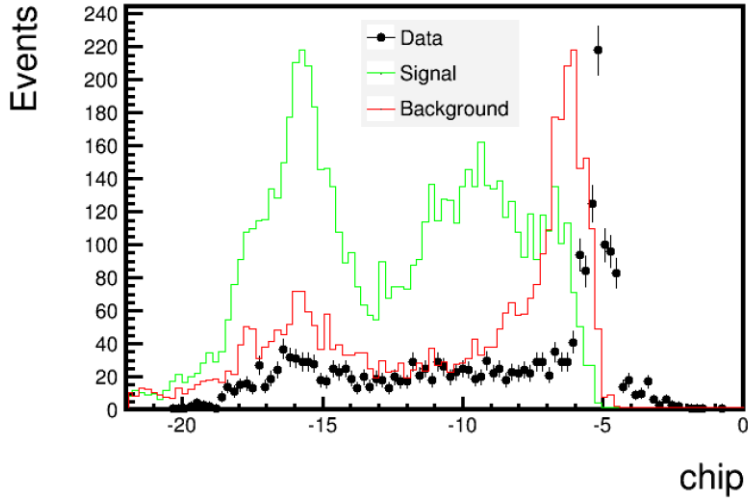
Background veto







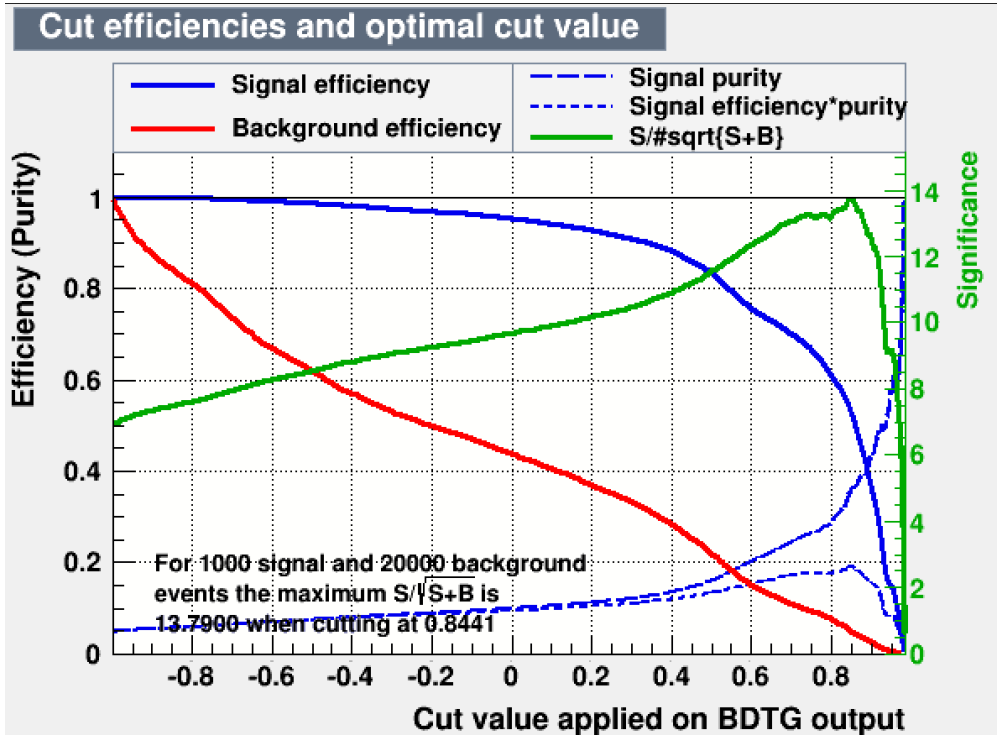




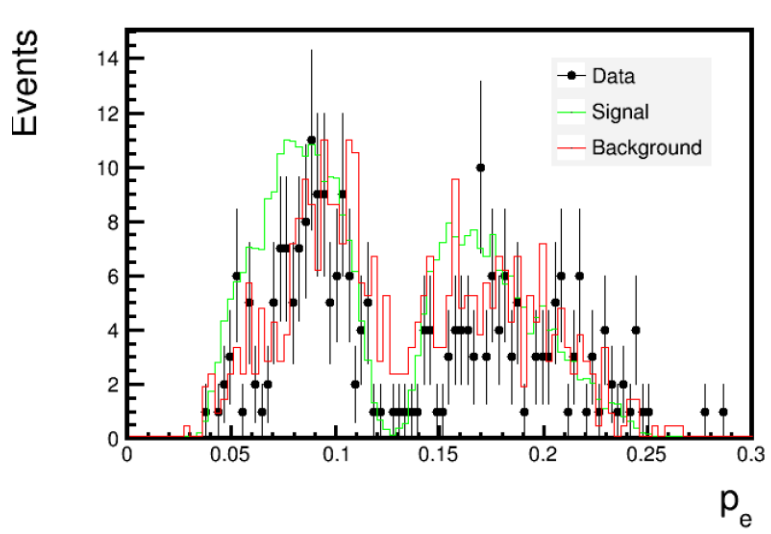
$$\frac{(dE/dx)_{measured} - (dE/dx)_{expected,i}}{\sigma_i}$$

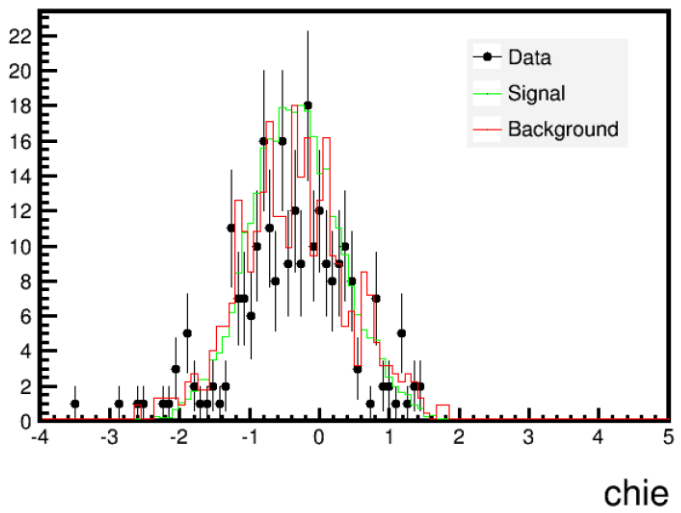
BDTG method

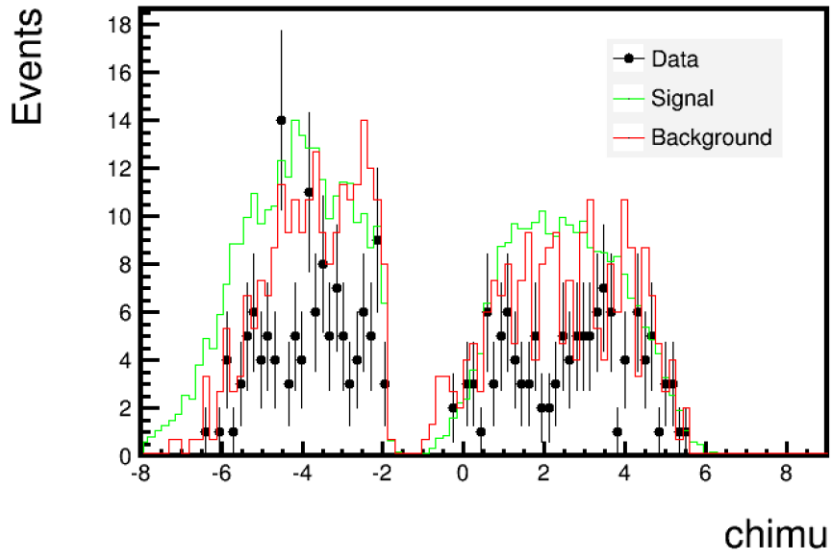
- *variable*：chie, chimu, chipi, chik, chip
- Train samples： 22360 signal mc and 7205 background mc

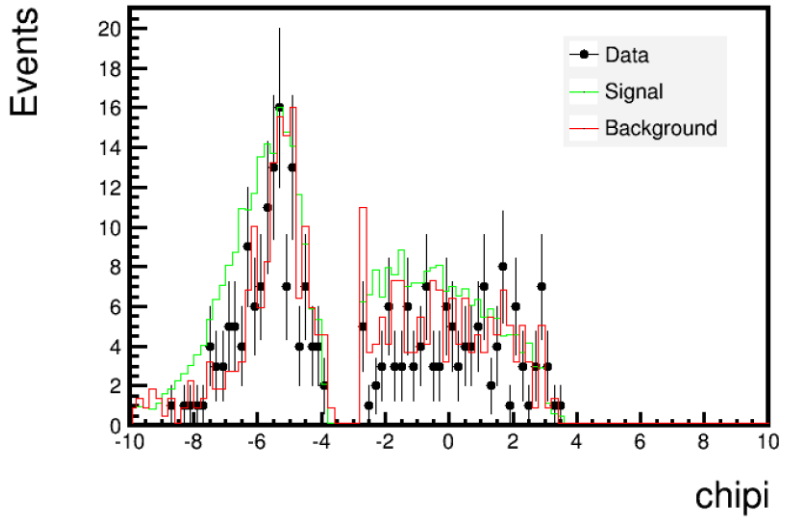


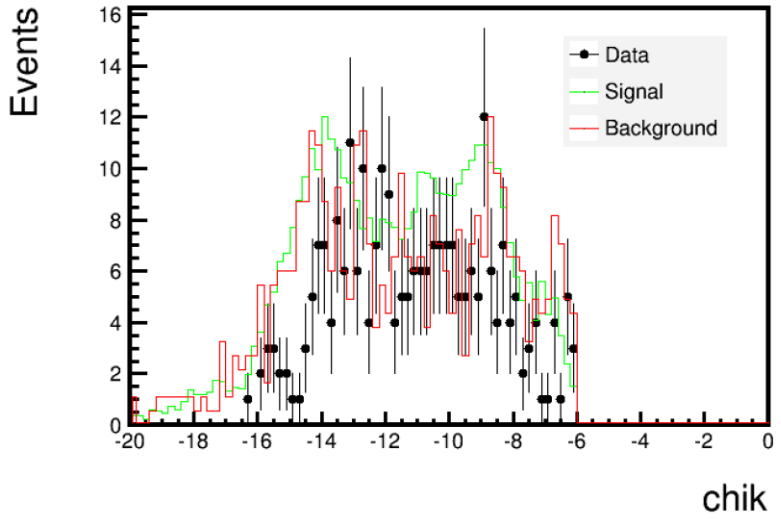
Background veto

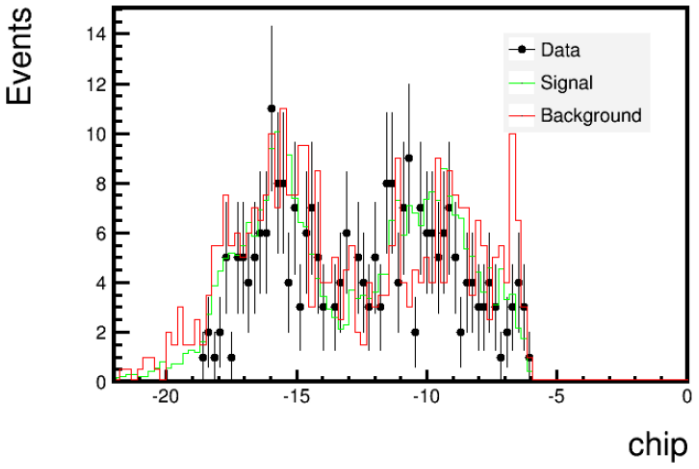




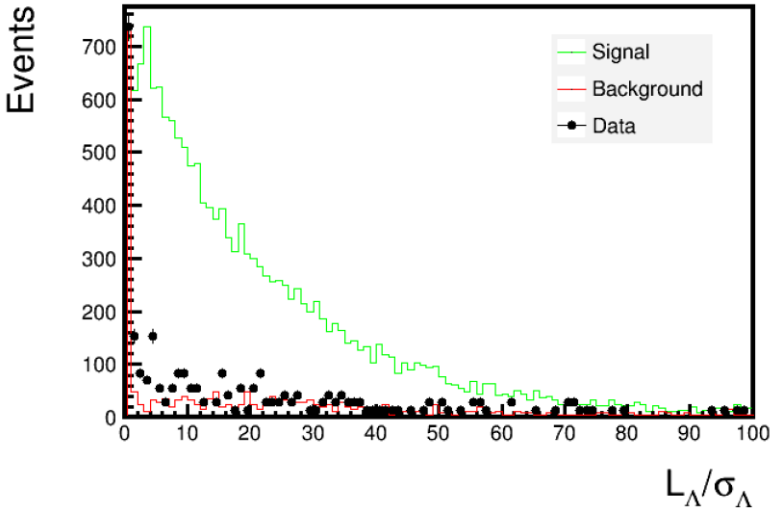


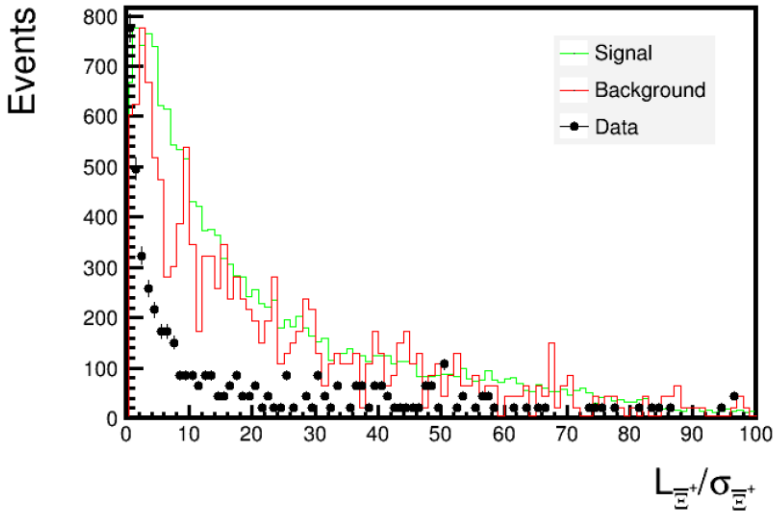


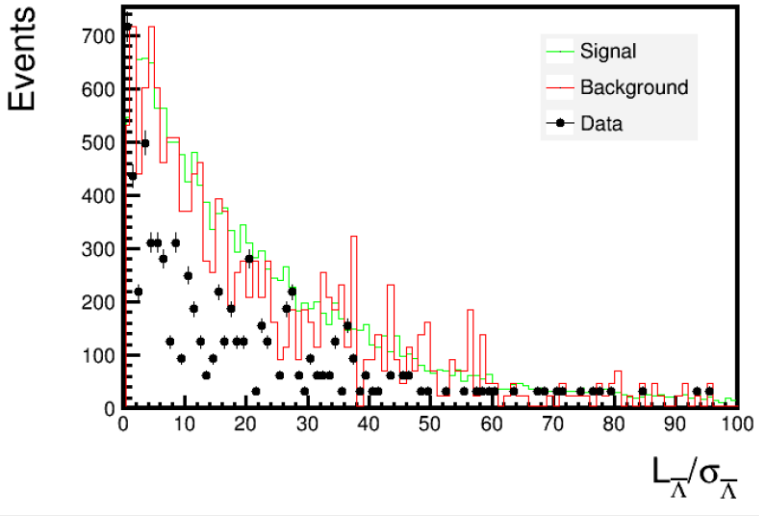


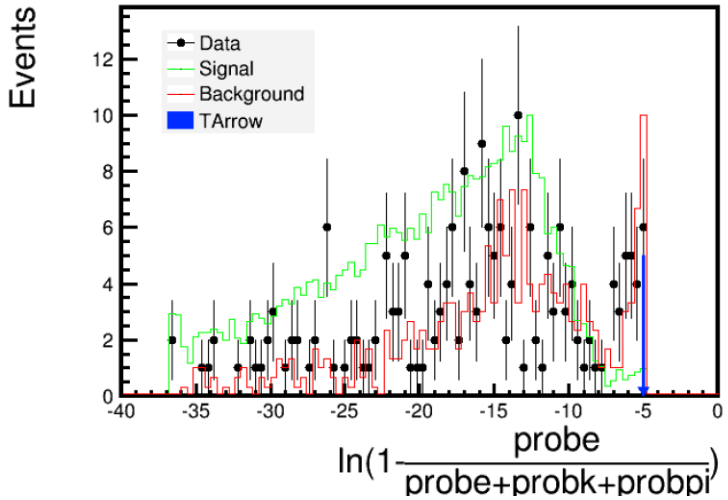


Background veto



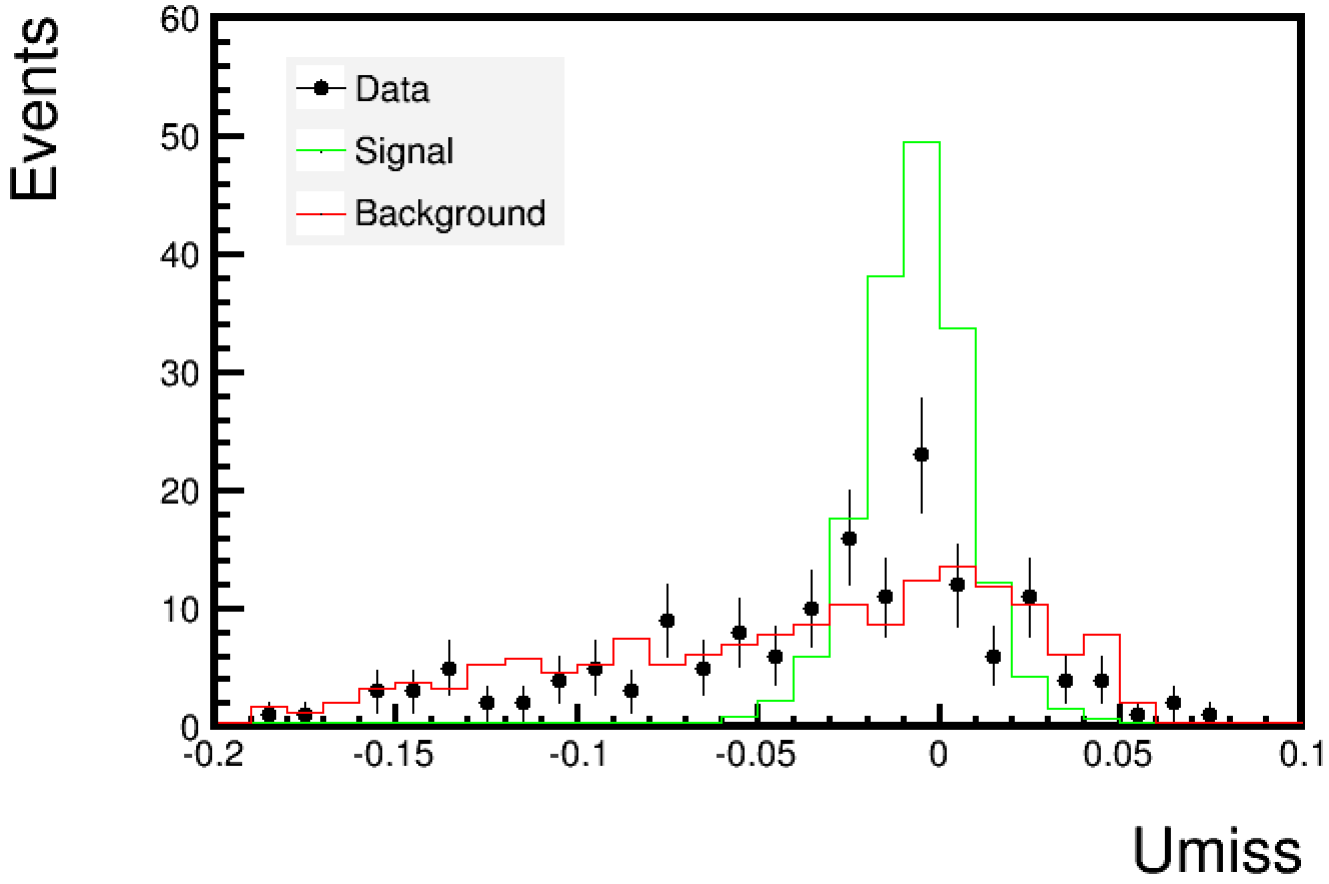






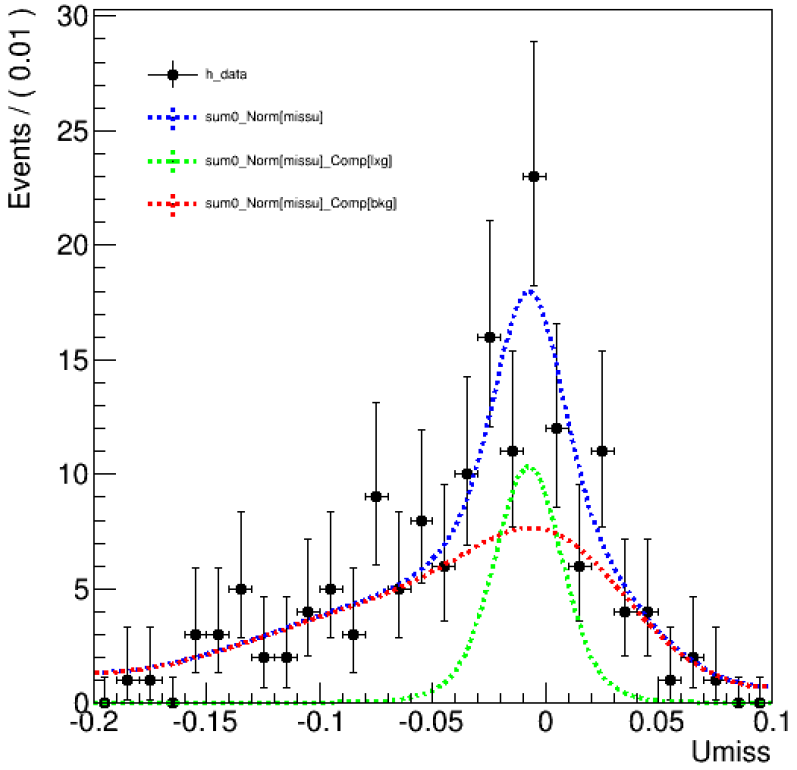
- $\ln\left(1-\frac{probe}{probe+probpi+probk}\right)<-10 \quad or \quad \frac{probe}{probe+probpi+probk}>0.99995$
- $\frac{\mathrm{decaylength}_\Lambda}{decaylengtherr_\Lambda}>2$

Background veto



BDTG method

➢ $BDTG > 0.8$



✓ Signal Shape+ Background shape $\otimes Gaussian$

◆ $Signal\ yield$: 41 ± 20
◆ $Background\ yield$: 116 ± 20

◆ $Signal\ mc\ efficiency$: 0.031
◆ $Background\ mc\ efficiency$: 2.82×10^{-5}

◆ $\frac{Expected\ signal\ yield}{expected\ bkg\ yield} = \frac{5.63\times10^{-4}\times0.031}{0.99887\times2.82\times10^{-5}} = 0.62$

◆ $Significance\ is\ about\ 3.6\sigma$

Next to do

- DIY signal mc will be used.
- More detailed study will be done to improve the result.