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Simulations of $\bar{p}p \to \Xi^+\Xi^-$

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Outline

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Parity violation in weak decay of hyperon

For a spin 1/2 hyperon decaying to a spin 1/2 baryon and a pion, conservation of total angular momentum implies $L = 0$ or 1. Parity of final state is given by $(-1)^L$. Since parity is not conserved both the S- and P-wave of the decay exist

$$M = S + P\bar{\sigma} \cdot \hat{p}_\pi \tag{1}$$

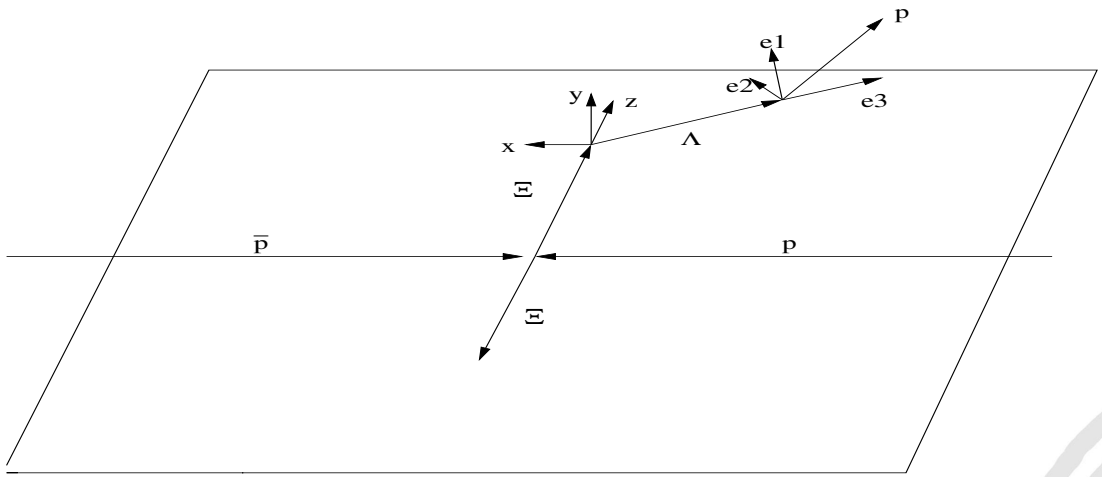
Define decay parameters

$$\alpha = \frac{2\mathrm{Re}(S^*P)}{|S|^2 + |P|^2}, \qquad \beta = \frac{2\mathrm{Im}(S^*P)}{|S|^2 + |P|^2}, \qquad \gamma = \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2} \tag{2}$$

Including $\alpha^2 + \beta^2 + \gamma^2 = 1$, we can instead define

$$\tan\phi = \frac{\beta}{\gamma}$$
$$\left(\text{with } \beta = \sqrt{1-\alpha^2}\sin\phi \text{ and } \gamma = \sqrt{1-\alpha^2}\cos\phi\right) \tag{3}$$

Definition of rest systems in $\bar{p}p \to \Xi^+\Xi^- \to \bar{\Lambda}\pi^+\Lambda\pi^-$



$$\hat{x} = \hat{y} \times \hat{z}$$

$$\hat{y} = \frac{\bar{p}_{\text{beam}} \times \bar{p}_{\Xi}}{|\bar{p}_{\text{beam}} \times \bar{p}_{\Xi}|} \qquad (4)$$

$$\hat{z} = \hat{p}_{\Xi}$$

$$\hat{e}_1 = \hat{e}_2 \times \hat{e}_3$$

$$\hat{e}_2 = \frac{\hat{y} \times \bar{p}_{\Lambda}}{|\hat{y} \times \bar{p}_{\Lambda}|} \qquad (5)$$

$$\hat{e}_3 = \hat{p}_{\Lambda}$$

Decay parameters and polarisation in $\bar{p}p \to \Xi^+\Xi^- \to \bar{\Lambda}\pi^+\Lambda\pi^-$

The angular distributions of the decay Λ in the Ξ rest frame are flat in the x- and z-direction, and in the y-direction given by

$$I(\theta_\Lambda) = 1 + \alpha_\Xi P_\Xi \cos\theta_\Lambda \tag{6}$$

The angular distributions of the decay p in the Λ rest frame are

$$\begin{aligned} I(\theta_{p,x}) &= 1 - \frac{\pi}{4}\alpha_\Lambda\gamma_\Xi P_\Xi \cos\theta_{p,x} \\ I(\theta_{p,y}) &= 1 + \frac{\pi}{4}\alpha_\Lambda\beta_\Xi P_\Xi \cos\theta_{p,y} \\ I(\theta_{p,z}) &= 1 + \alpha_\Lambda\alpha_\Xi \cos\theta_{p,z} \end{aligned} \tag{7}$$

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Simulations

- Release 0.15.3
- 4 GeV/c beam momentum
- 4956000 generated events
- 64% branching ratio for $\Lambda \rightarrow p\pi^-$ $\Rightarrow$ in $\approx 41\%$ both Λ decay in the way we are interested in $\Rightarrow$ 2025592 such events
- Flat angular distribution of Ξ (no experimental information)
- 100% Ξ polarisation simulated using weights

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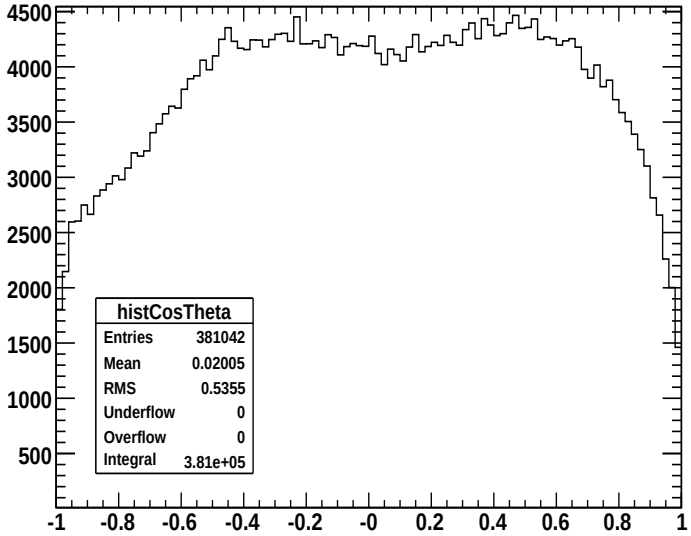
Efficiency

381042 events are reconstructed $\Rightarrow$ efficiency $\approx 19\%$



$\cos\theta_\Xi$ dependence of efficiency

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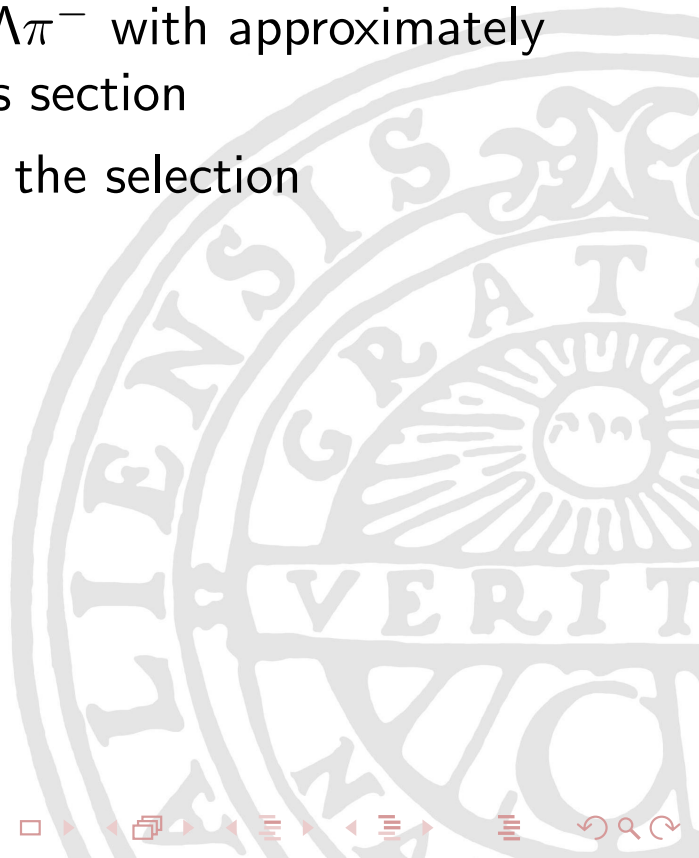
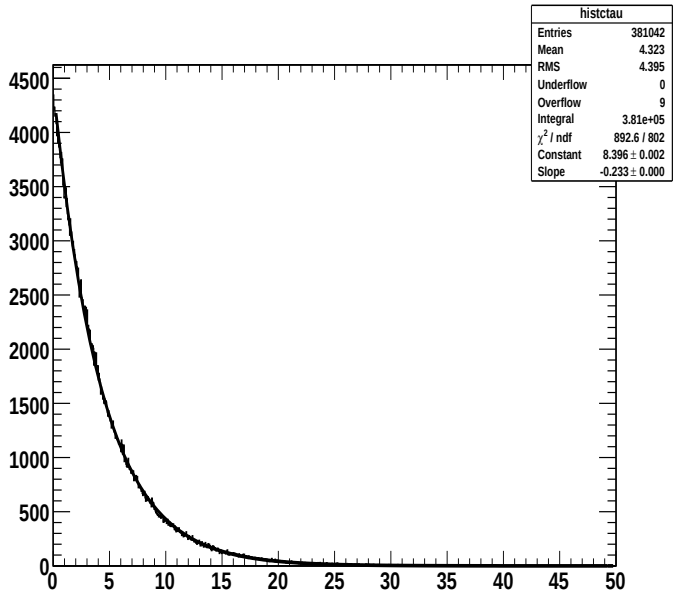
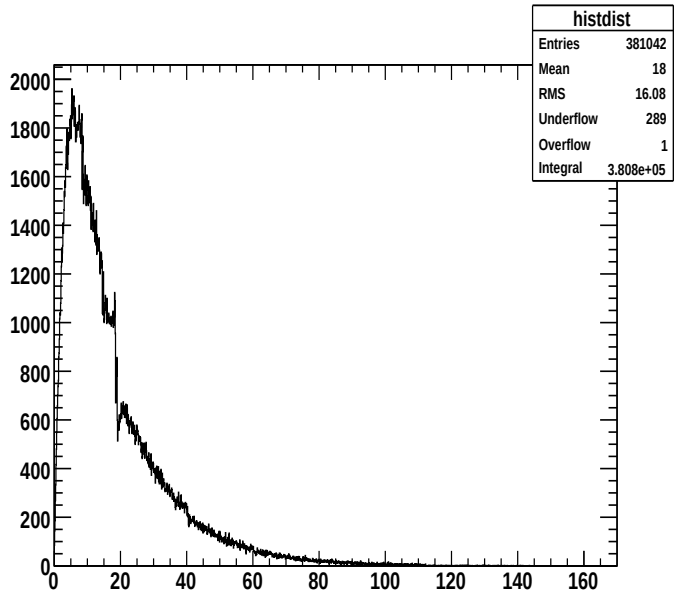
Background

- Main background channel is $\bar{p}p \to \Sigma(1385)^+\Sigma(1385)^- \to \bar{\Lambda}\pi^+\Lambda\pi^-$ with approximately one order of magnitude larger cross section
- Only 4 out of 1000000 events pass the selection



Reconstruction of $c\tau$

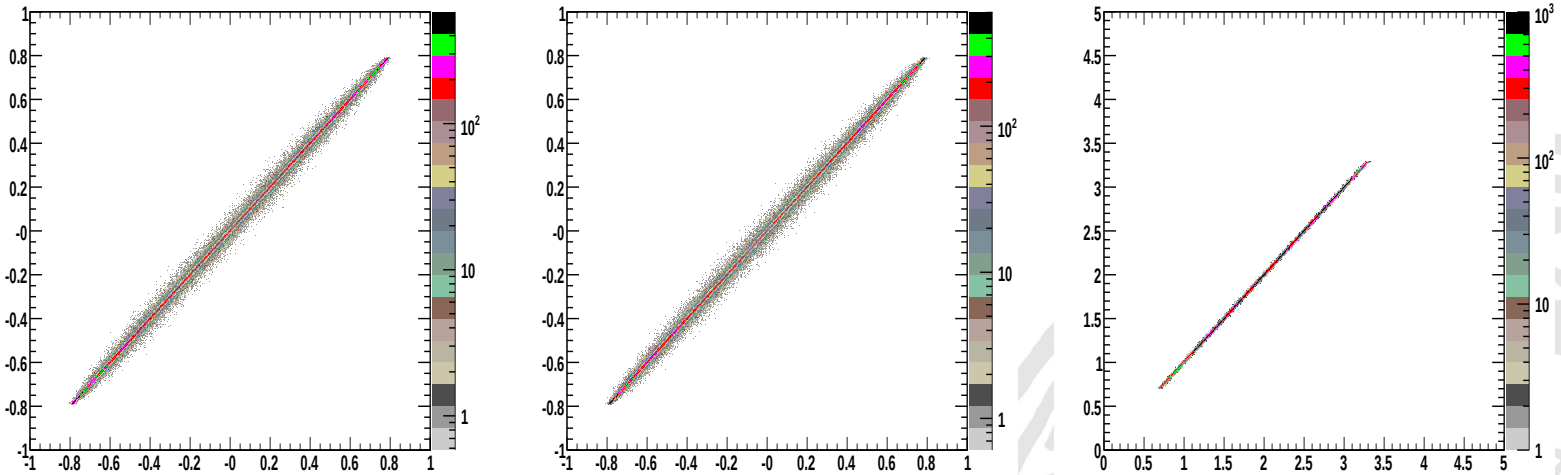




Reconstructed $c\tau$ is 4.3 cm. PDG value is 4.8 cm.

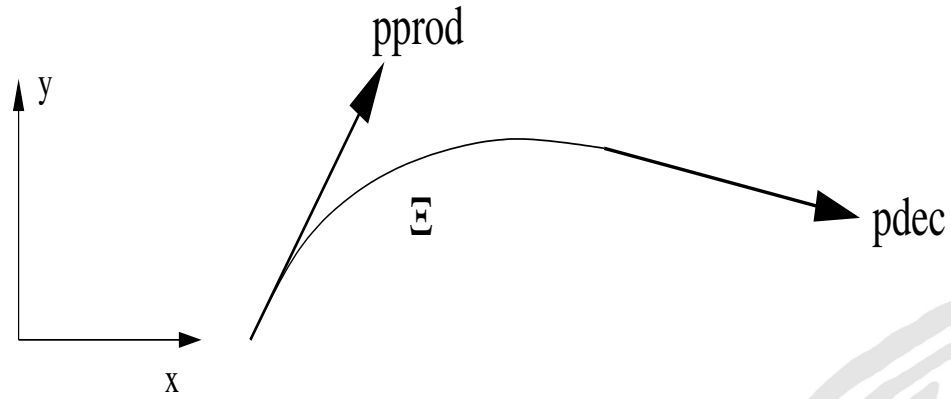
Strange dip at 20 cm in distribution of Λ vertex in z-direction.

Reconstruction of Ξ^+ momentum



Reconstructed Ξ^+ momentum vs Monte Carlo in x-, y- and z-direction.

Correction for bending of Ξ^+ in the magnetic field

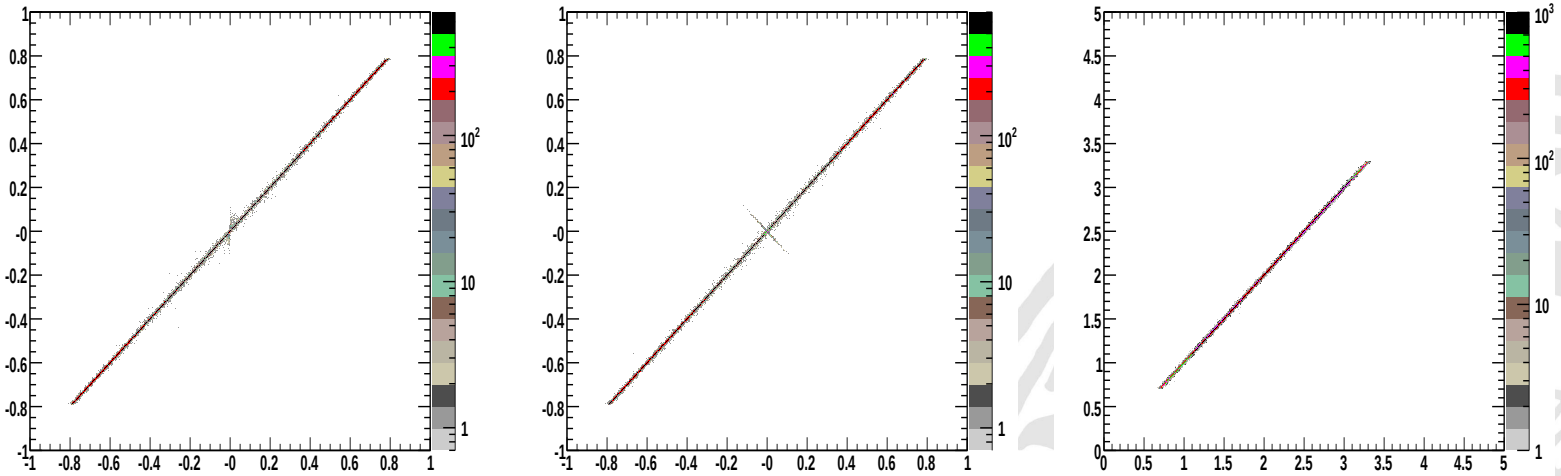


Since the Ξ have electromagnetic charge they will be bent in the xy-plane by the magnetic field. The Ξ rest systems are constructed and polarisation is applied using p_{prod}, while the reconstructed momentum is p_{dec}. p_{prod} can be obtained from p_{dec} using

$$R = \frac{p_\perp}{0.3B} \tag{8}$$

(from PDG)

Correction for bending of Ξ^+ in the magnetic field



Reconstructed Ξ^+ momentum vs Monte Carlo in x-, y- and z-direction.

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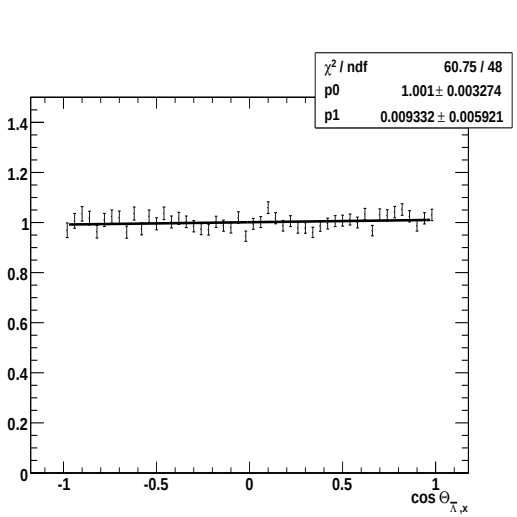
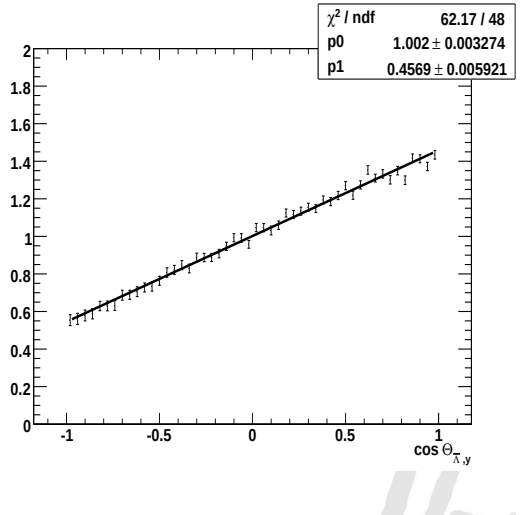
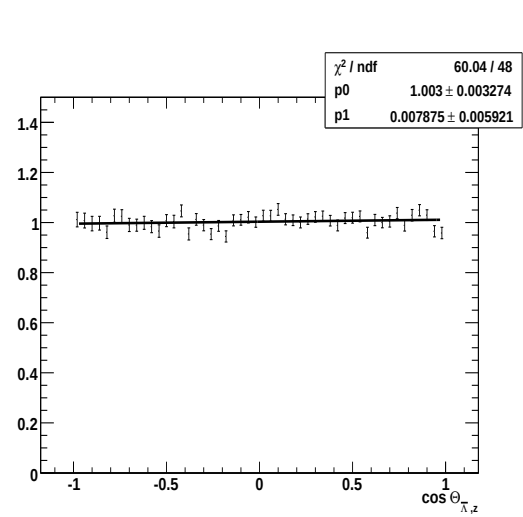
Reconstruction of α_Ξ, ϕ_Ξ and P_Ξ

Half of the events (190521) are used to do a calibration for the difference in detector efficiency for different angles. From the slopes of the angular distributions of Λ and p in the different rest systems, values of α_Ξ, ϕ_Ξ and P_Ξ can be extracted.

Efficiency calibrated angular distributions of decay $\bar{\Lambda}$

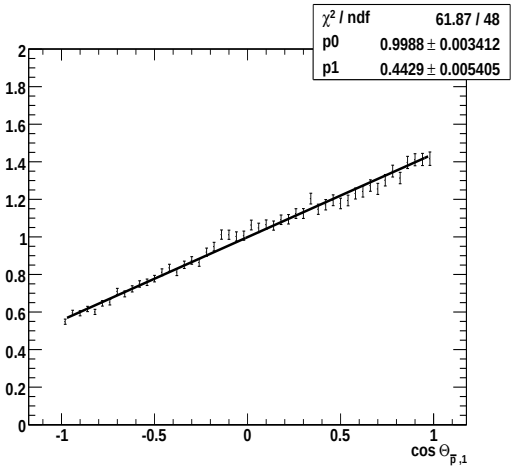


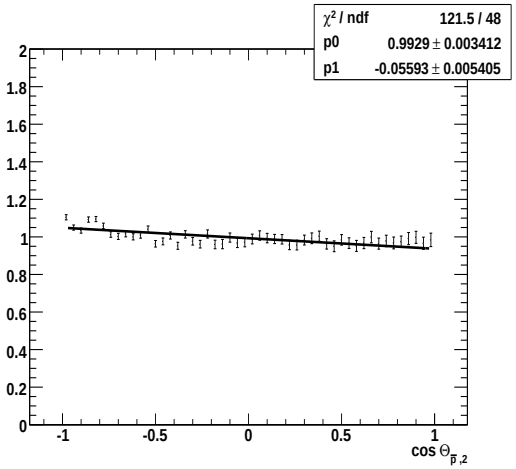


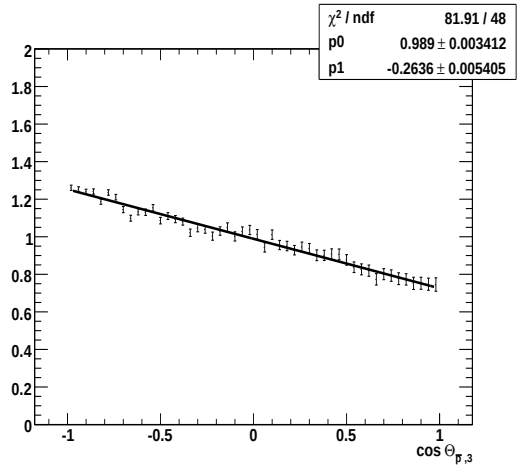


$$\text{slope} = \alpha_{\Xi} P_{\Xi}$$

Efficiency calibrated angular distributions of decay $\bar{p}$







$$-\frac{\pi}{4}\alpha_\Lambda\sqrt{1-\alpha_\Xi^2}\cos\phi_\Xi P_\Xi$$

$$\frac{\pi}{4}\alpha_\Lambda\sqrt{1-\alpha_\Xi^2}\sin\phi_\Xi P_\Xi$$

$$\alpha_\Lambda\alpha_\Xi$$

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1C-fit to get α_Ξ, ϕ_Ξ and P_Ξ

	Ξ^+		Ξ^-	
	reconstructed	input	reconstructed	input
P	1.008±0.010	1	1.030±0.009	1
α	0.441±0.005	0.458	-0.457±0.005	-0.458
ϕ	7.2°±0.7°	2.1°	-0.9°±0.7°	-2.1°

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Conclusions

- 19% efficiency
- No problem with background from $\bar{p}p \to \Sigma(1385)^+\Sigma(1385)^- \to \bar{\Lambda}\pi^+\Lambda\pi^-$
- A bit too low reconstructed $c\tau$ for Ξ as for Λ , strange dip in Λ decay vertex at 20 cm in z-direction
- Ξ polarisation and decay parameters are reconstructed reasonably well