# Update on the $\overline{p}p \rightarrow \overline{\Xi}\Xi$ Analysis

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# Motivation

- Until now: feasibility studies of $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$

- Spin observables extraction using spin density matrix formalism with spin $1/2 \rightarrow 1/2 + 0$ decay $\Lambda \rightarrow p\pi$

- The $\Xi \rightarrow \Lambda\pi$ decay has same quantum numbers
  $\rightarrow$ Same formalism can be used!

In this presentation

- Formulate selection criteria

- Use MC truth matching to benchmark signal/combinatorial background

- DPM background not considered (yet)

# Simulation parameters

Simulations are done with:

- Release dec17p2b.
- fairsoft_may16p1
- Fairroot v17.10b

Decay of $\Xi$ handled by Geant4:

- Ensures propagation of $\Xi$ in $B$-field
- Event sample: 8726

Parameters:

- Forward-peaking distribution
- Antiproton beam: $p_{\bar{p}} = 7.0$ GeV/c
- Full Detector Setup
- Ideal Mass Hypothesis for Kalman Filter
- Ideal Pattern Recognition
- Ideal Particle Identification

# Preselection using Decay Tree Fit

Preselection criteria:

- Combine $p\pi^-$ to form $\Lambda$ candidates
- Select $|m_\Lambda - M(p\pi^-)| < 0.1$ GeV/c$^2$
- Combine $\Lambda\pi^-$ to form $\Xi^-$ candidates
- Select $|m_\Xi - M(\Lambda\pi^-)| < 0.1$ GeV/c$^2$
- DTF $\Xi^- \to \Lambda\pi^- \to p\pi^-\pi^-$
- Reject candidate if $P(\mathrm{DTF}(\Lambda,\pi^-)) < 0.01$
- Repeat for $\overline{\Xi}^+$ candidates
- Combine $\overline{\Xi}^+\Xi^-$ to form $\overline{p}p$ system
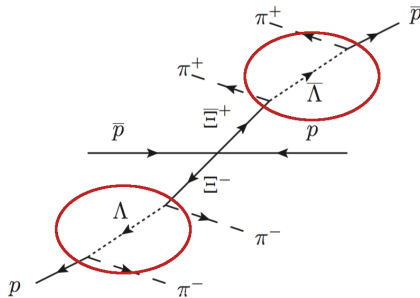
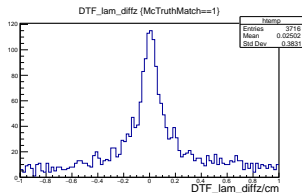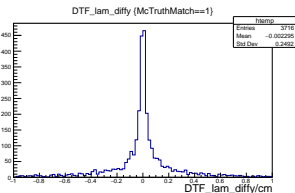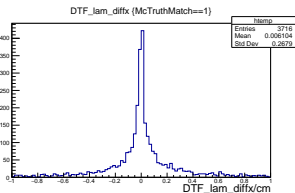# Decay Tree Fit of $\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$

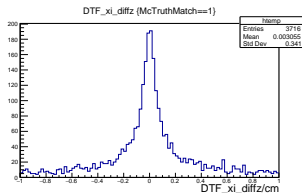Decay tree fit of $\Xi$ formulated in following way:

- Set $\Xi$ and $\Lambda$ decay points as unknown variables
- Mass of $\Lambda$ constrained to pdg value

Advantage over cascaded vertex- and mass fits:

- Two vertex fits and a mass fit performed simultaneously.
- All constraints being respected at the same time.

# Errors of vertex positions in $\Xi^- \to \Lambda\pi^- \to p\pi^-\pi^-$
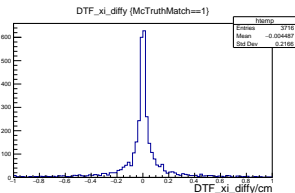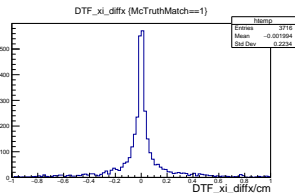
# Preselection Efficiencies

| Sample | True | False | T/F | $\epsilon$ |
|:---:|:---:|:---:|:---:|:---:|
| $\bar{\Lambda}$ | 4850 | 4804 | 1.01 | 56% |
| $\Lambda$ | 4995 | 5488 | 0.91 | 57% |
| $\bar{\Xi}^+$ | 3716 | 3720 | 1.00 | 43% |
| $\Xi^-$ | 3833 | 4078 | 0.94 | 44% |
| $\bar{\Xi}^+\Xi^-$ | 919 | 129 | 7.12 | 11% |

- $S/B = 7.12$ not sufficient for spin observables extraction
  Further selection necessary
- Need to select one $\bar{\Xi}^+\Xi^-$ candidate per event

# Final selection

Final selection criteria:

- Vertex fit $\overline{\Xi}^+\Xi^-$
  To propagate variables
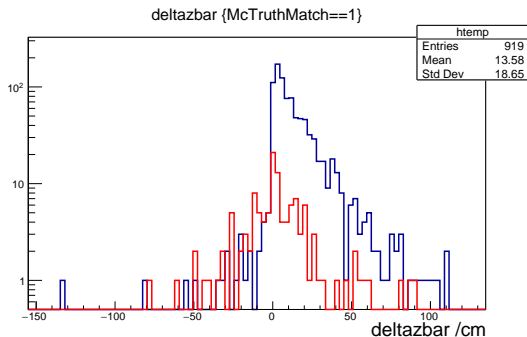  from vertex to IP

- Four constraint fit $\overline{\Xi}^+\Xi^-$

- Select $r_0(\overline{\Xi}^+\Xi^-) < 1$ cm

- Select $> 3$ rad

- Select $\Delta z = z(\Lambda) - z(\Xi) > 0$ cm

- Choose $\overline{\Xi}^+\Xi^-$ pair with smallest
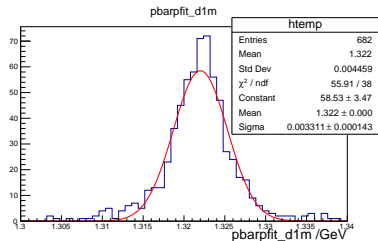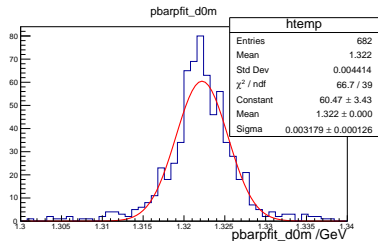  4C fit $\chi^2$
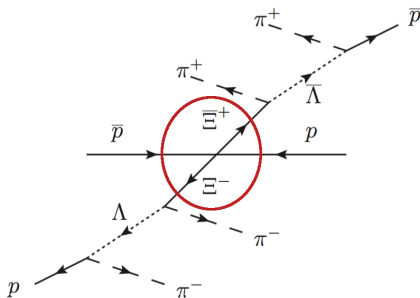
# Final selection



- For correctly combined events, Λ decay point downstream $w.r.t$ Ξ decay point $\Delta z > 0$

- Combinatorial background $\Delta z$ centered around 0

# Final selection

| Sample | True | False | T/F | $\epsilon$ |
|--------|------|-------|-----|-----|
| $\overline{\Lambda}$ | 4850 | 4804 | 1.01 | 56% |
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| $\overline{\Xi}^+\Xi^-$ | 919 | 129 | 7.12 | 11% |
| Final $\overline{\Xi}^+\Xi^-$ | 678 | 4 | 170 | 7.8% |

- Efficiency of 7.8% after final selection
- No contamination of combinatorial background $S/B = 170$.
  Suitable for spin observables extraction

# Ξ Invariant Mass



- Using output variables of 4C fit
- $\overline{\Xi}^+$ mass resolution: $\sigma = 3.2$ MeV/$c^2$
  $\Xi^-$ mass resolution: $\sigma = 3.3$ MeV/$c^2$
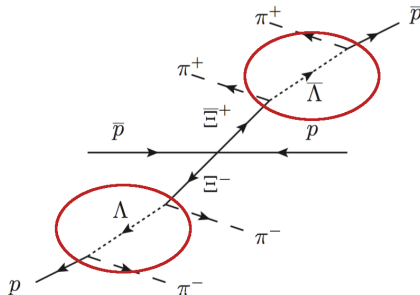
Comparison with cascade of fits

# Preselection and event reconstruction

Preselection criteria:

- Combine $p\pi^-$
- Select $|m_\Lambda - M(p\pi^-)| < 0.1$ GeV/c$^2$
- Vertex & Mass fit, reject candidate if
  $P(\mathrm{Vtx}(p,\pi^-)) < 0.01$
  $P(\mathrm{Mass}(p,\pi^-)) < 0.01$
- Combine $\Lambda\pi^-$
- Select $|m_\Xi - M(\Lambda\pi^-)| < 0.1$ GeV/c$^2$
- Vertex fit, reject candidate if
  $P(\mathrm{Vtx}(\Lambda,\pi^-)) < 0.01$
- Repeat for $\overline{\Xi}^+$ candidates
- Combine $\overline{\Xi}^+\Xi^-$ to form $\overline{p}p$ system

# Conventional fitting tools

Decay Tree Fit

| Sample | True | False | T/F |
|---|---|---|---|
| $\bar{\Lambda}$ | 4850 | 4804 | 1.01 |
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Conventional Fits

| Sample | True | False | T/F |
|---|---|---|---|
| $\bar{\Lambda}$ | 4850 | 4804 | 1.01 |
| $\Lambda$ | 4995 | 5488 | 0.91 |
| $\bar{\Xi}^+$ | 3688 | 1355 | 2.76 |
| $\Xi^-$ | 3782 | 1468 | 2.58 |
| $\bar{\Xi}^+\Xi^-$ | 1382 | 885 | 1.56 |
| Final $\bar{\Xi}^+\Xi^-$ | 895 | 42 | 21.3 |

+ Overall efficiency higher using conventional fits
  Conventional fits: 10%, Decay Tree Fit: 7.8%

- Worse supperssion of combinatorial background

# Conventional fitting tools

Comparison of $\overline{\Xi}^+$ momentum pull distribution from 4C fit
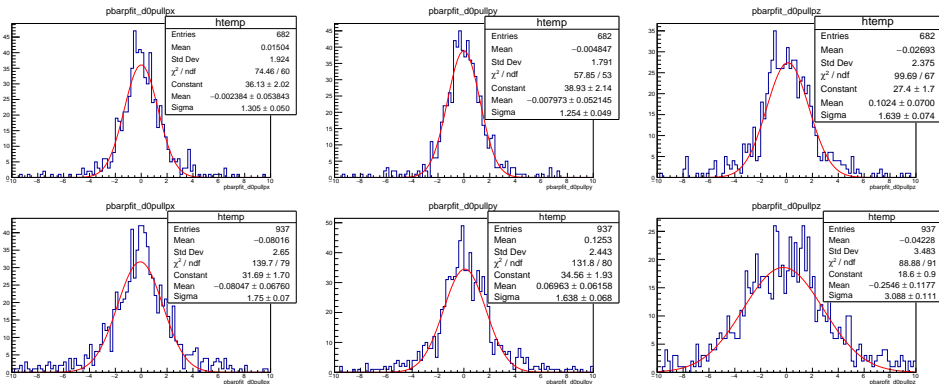


- Pull variables should be $\mathcal{N}(0,1)$ distributed
- Pulls with conventional fitting tools larger deviation and bias
  $\rightarrow$ Suggest poorer quality of input variables for 4C fit

# Summary & Outlook

Summary:

- Simulation and analysis tools updated
- Exclusive reconstruction of $\overline{\Xi}^+\Xi^-$, $\Xi \to \Lambda$, $\Lambda \to p\pi$
    - Efficiency: $\epsilon = 7.8\ \%$
    - Signal/background: $S/B = 170$
      (not considering DPM background)
    - $\overline{\Xi}^+$ mass resolution: $\sigma = 3.2$ MeV/c$^2$
      $\Xi^-$ mass resolution: $\sigma = 3.3$ MeV/c$^2$

Outlook:

- Simulation of DPM background
  $\sigma(\overline{p}p \to \mathrm{inelastic}) = 44.5 \cdot 10^3\ \mu\mathrm{b}$, $\sigma(\overline{p}p \to \overline{\Xi}^+\Xi^-) = 2\ \mu\mathrm{b}$
- Spin observables extraction

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- Spin observables extraction

## Thank you for your attention!

# Backup