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

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on behalf of the $\overline{\text{P}}$ANDA collaboration

$\overline{\text{P}}$ANDA collaboration meeting
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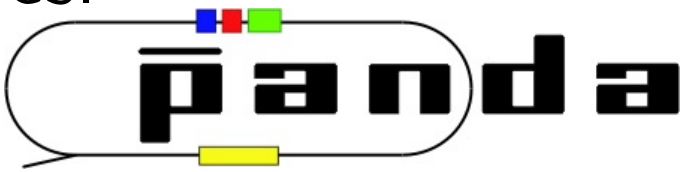
GSI



Outline

- Feasibility studies of $\overline{p}p \to \overline{\Xi}^{+}\Xi^{-}$ at $p_{\mathrm{beam}} = 7.0$ GeV/c
- Spin observables extraction using spin density matrix formalism
- Will be presented on Thursday during plenary sessions

In this presentation

- Test effects on reconstruction efficiency when changing differential cross section
- Test feasibility of measuring spin observables of $\overline{p}p \to \overline{\Xi}^{+}\Xi^{-}$ at $p_{\mathrm{beam}} = 4.6$ GeV/c

Simulation parameters

Simulations are done with:

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

Decay of Ξ handled by Geant4:

- Ensures propagation of Ξ in B-field
- Event sample: $\sim 8.5 \cdot 10^5$

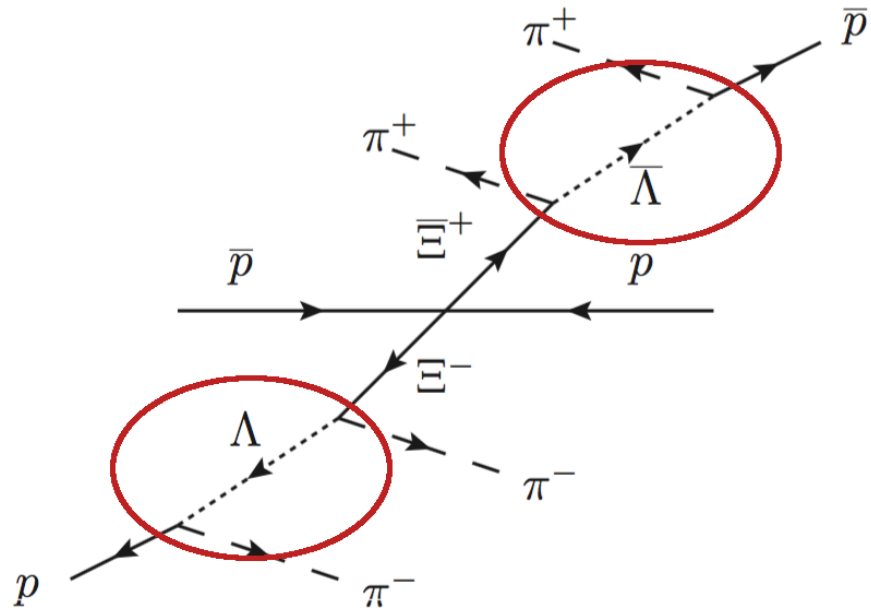
Parameters:

- Antiproton beam:
  $p_{\overline{p}} = 7.0$ GeV/c
  $p_{\overline{p}} = 4.6$ GeV/c
- Full Detector Setup
- Ideal Mass Hypothesis for Kalman Filter
- Ideal Pattern Recognition
- Ideal Particle Identification

Preselection - first set

Preselection criteria:

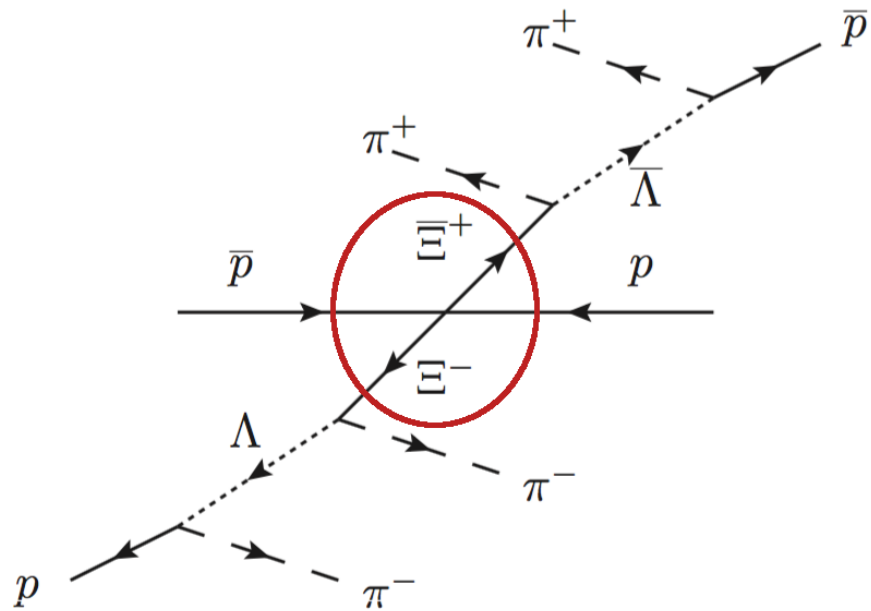
- Combine $p\pi^-$ to form Λ candidates
- Select $|m_\Lambda - M(p\pi^-)| < 50$ MeV/c^2
- Combine $\Lambda\pi^-$ to form Ξ^- candidates
- Select $|m_\Xi - M(\Lambda\pi^-)| < 50$ MeV/c^2
- DTF $\Xi^- \to \Lambda\pi^- \to p\pi^-\pi^-$
- Repeat for $\overline{\Xi}^+$ candidates
- Combine $\overline{\Xi}^+\Xi^-$ to form $\overline{p}p$ system



Preselection - second set

Final selection criteria:

- Vertex fit $\overline{\Xi}^{+}\Xi^{-}$
  To propagate variables
  from vertex to IP
- Select $\angle(\overline{\Xi}^{+}\Xi^{-}) > 3$ rad
- Select $\Delta z = z(\Lambda) - z(\Xi) > 0$ cm
- Four constraint fit $\overline{\Xi}^{+}\Xi^{-}$
- Choose $\overline{\Xi}^{+}\Xi^{-}$ pair with smallest
  4C fit χ^2



Preselection 1st set at $p_{\mathrm{beam}} = 7.0$ GeV/c

Sample	True	False	T/F	ϵ
$\overline{\Lambda}$	4.72×10^5	4.75×10^5	0.90	55%
Λ	4.84×10^5	5.39×10^5	0.99	57%
$\overline{\Xi}^+$	3.65×10^5	3.71×10^5	0.98	43%
Ξ^-	3.73×10^5	3.49×10^5	1.1	44%
$\overline{\Xi}^+\Xi^-$ 1st	8.9×10^4	1.2×10^4	7.6	10.4%

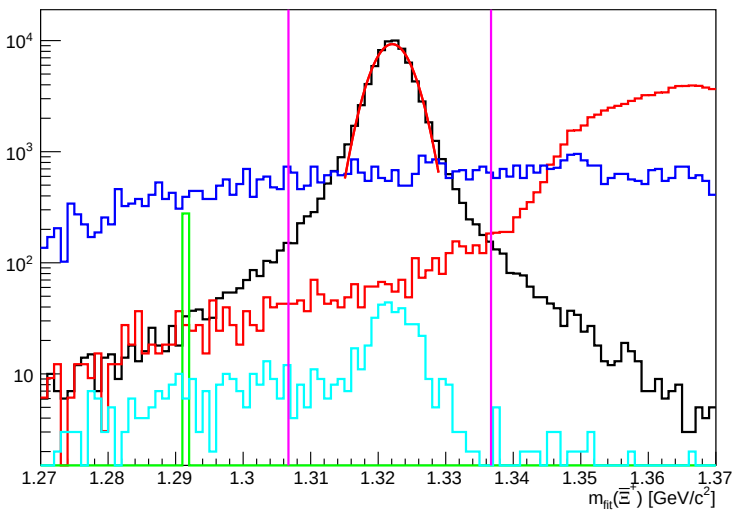
- Efficiency of 10.4% after first set of preselection
- Must impose further selection and choose one candidate per event
- Consider background channels

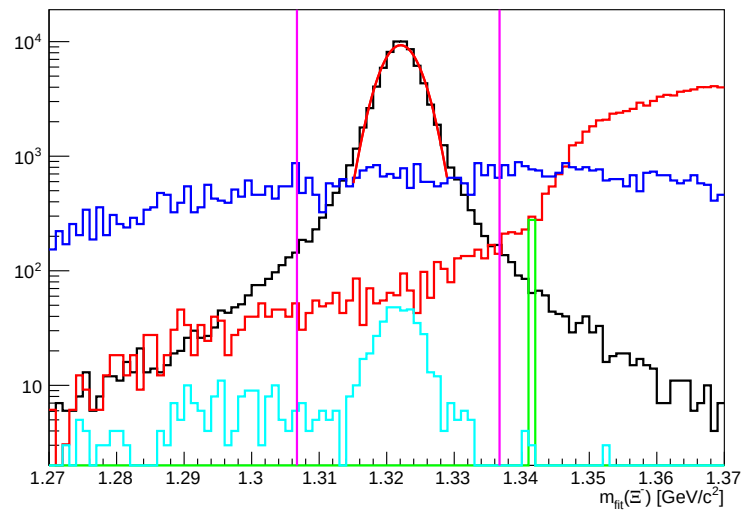
Final Selection - Ξ Invariant Mass at $p_{\mathrm{beam}} = 7.0$ GeV/c

- Gaussian fit: $m_{fit}(\overline{\Xi}^{+}) = 1322.1$ MeV/c^2 and $\sigma_{fit}(\overline{\Xi}^{+}) = 3.0$ MeV/c^2
- Gaussian fit: $m_{fit}(\Xi^{-}) = 1322.0$ MeV/c^2 and $\sigma_{fit}(\Xi^{-}) = 3.0$ MeV/c^2

Select $|m_{fit}(\Xi) - m_{pdg}(\Xi)| < 15\,\mathrm{MeV/c^2}$

- Black - $\overline{\Xi}^{+}\Xi^{-}$
- Red - $\overline{\Sigma}^{+}(1385)$
- Blue - $\overline{\Lambda}\Lambda\pi^{+}\pi^{-}$
- Green - $\overline{p}p2\pi^{+}2\pi^{-}$
- Cyan - Combi.



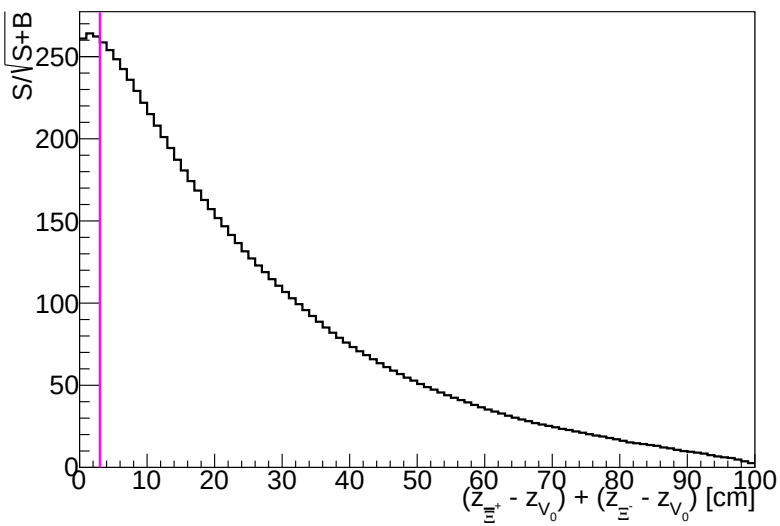


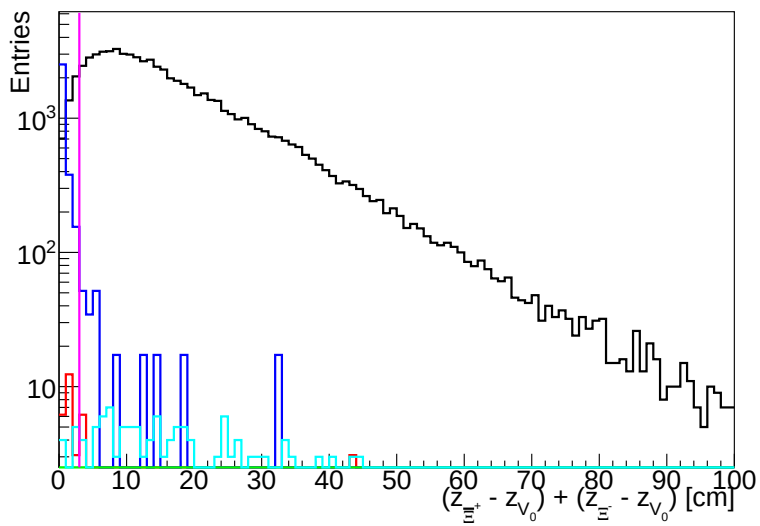
Final Selection - Displaced Vertex at $p_{\mathrm{beam}} = 7.0$ GeV/c

I.P reconstructed with vertex fit

- Ξ displaced from I.P
- Select
  $(z(\overline{\Xi}^{+}) - z(V_0)) + (z(\Xi^{-}) - z(V_0)) > 3$

- Black - $\overline{\Xi}^{+}\Xi^{-}$
- Red - $\overline{\Sigma}^{+}(1385)$
- Blue - $\overline{\Lambda}\Lambda\pi^{+}\pi^{-}$
- Green - $\overline{p}p2\pi^{+}2\pi^{-}$
- Cyan - Combi.





Final Efficiencies

Limits are 90% C.L.

Channel	$\Xi^+\Xi^-$	$\overline{\Sigma}(1385)^+\Sigma(1385)^-$	$\overline{\Lambda}\Lambda 2\pi^+2\pi^-$	$\overline{p}p2\pi^+2\pi^-$	DPM
Sample	8.5×10^5	10×10^7	10×10^7	10×10^7	10×10^7
σ_{eff} [μb]	0.123	4.33	24.1	390	58 300
Weight factor	1	3.06	17.06	278	41 214
Preselection 2nd	7.83×10^4	3.15×10^4	3.51×10^3	1	14
Final selection	6.76×10^4	3	14	0	0
N weighted	6.76×10^4	9	239	0	0
S/B	420	7.4×10^3	283	> 106	> 0.7

- Final signal efficiency of $\epsilon = 7.9\%$
- High purity, $S/B > 100$ across relevant background channels

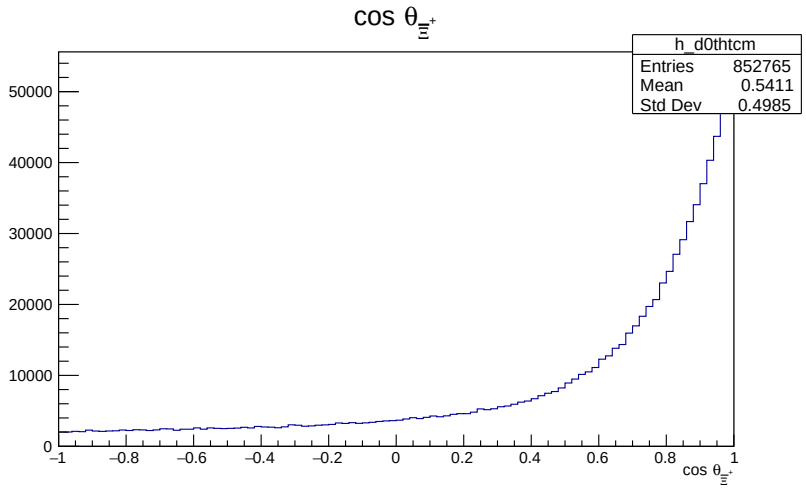
Differential cross section

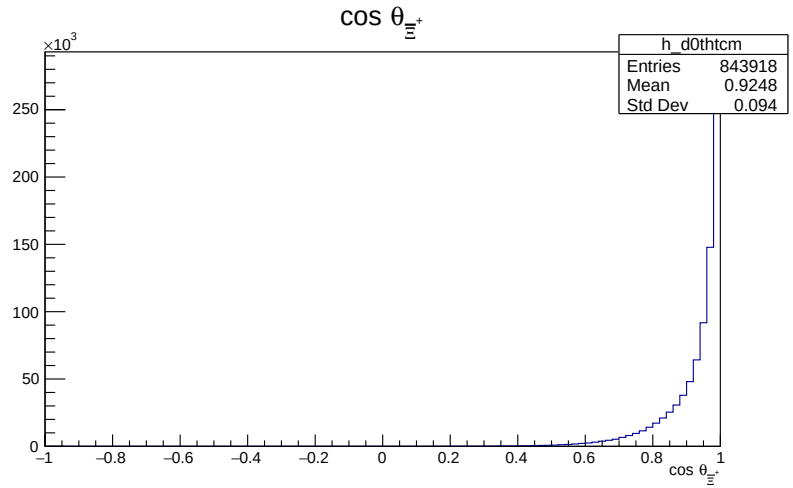
Introduce forward-peaking distribution and see change in final efficiency

Forward peaking distributions

Angular dsitribution modeled with empirical function, t' reduced momentum transfer

$$I \propto abe^{-bt'} + cde^{-dt'}$$





More lenient case

$\epsilon = \mathbf{7.5\%}$

Extreme case, parameters similar to $\overline{p}p \to \overline{\Sigma}^0\Lambda$ at $p_{\mathrm{beam}} = 6.0$ GeV/c

$\epsilon = \mathbf{5.0\%}$

Spin Observables at $p_{\mathrm{beam}} = 4.6$ GeV/c

Feasibility of measuring spin observables at $p_{\mathrm{beam}} = 4.6$ GeV/c

Preselection 1st set at $p_{\mathrm{beam}} = 4.6$ GeV/c

Sample	True	False	T/F	ϵ
$\overline{\Lambda}$	5.14×10^5	5.43×10^5	0.95	60%
Λ	5.25×10^5	6.15×10^5	0.85	62%
$\overline{\Xi}^+$	3.87×10^5	4.07×10^5	0.95	46%
Ξ^-	3.95×10^5	4.41×10^5	0.90	46%
$\overline{\Xi}^+\Xi^-$ 1st	9.7×10^4	8.9×10^3	11	11.4%

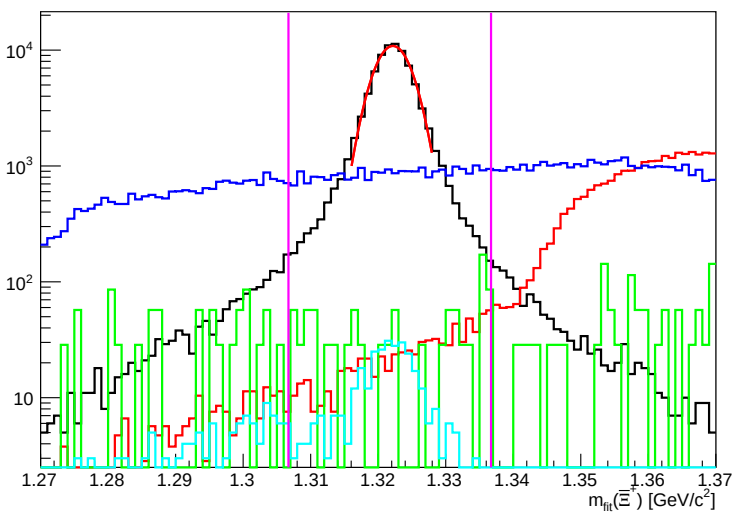
- Efficiency of 11.4% after first set of preselection
- Must impose further selection and choose one candidate per event
- Consider background channels

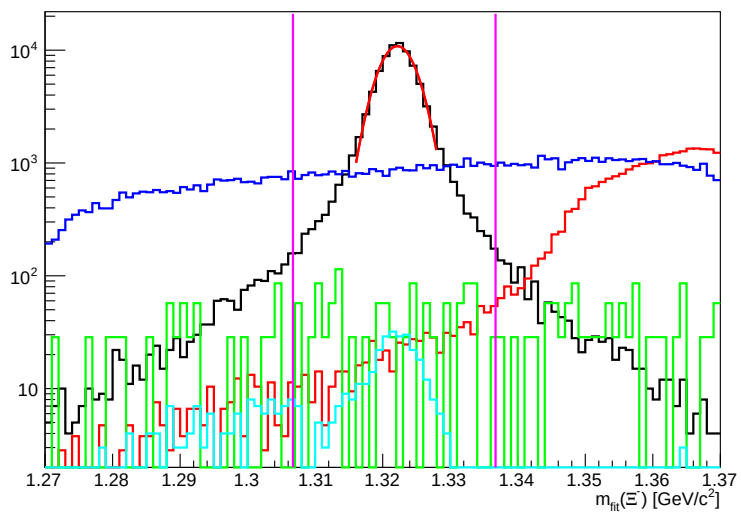
Final Selection - Ξ Invariant Mass at $p_{\mathrm{beam}} = 4.6$ GeV/c

- Gaussian fit: $m_{fit}(\overline{\Xi}^{+}) = 1322.2$ MeV/c^2 and $\sigma_{fit}(\overline{\Xi}^{+}) = 2.8$ MeV/c^2
- Gaussian fit: $m_{fit}(\Xi^{-}) = 1322.2$ MeV/c^2 and $\sigma_{fit}(\Xi^{-}) = 2.8$ MeV/c^2

Select $|m_{fit}(\Xi) - m_{pdg}(\Xi)| < 15\,\mathrm{MeV/c^2}$

- Black - $\overline{\Xi}^{+}\Xi^{-}$
- Red - $\overline{\Sigma}^{+}(1385)$
- Blue - $\overline{\Lambda}\Lambda\pi^{+}\pi^{-}$
- Green - $\overline{p}p2\pi^{+}2\pi^{-}$
- Cyan - Combi.





Final Selection - Displaced Vertex at $p_{\mathrm{beam}} = 4.6$ GeV/c

I.P reconstructed with vertex fit

- Ξ displaced from I.P
- Select
  $(z(\overline{\Xi}^{+}) - z(V_0)) + (z(\Xi^{-}) - z(V_0)) > 3$

- Black - $\overline{\Xi}^{+}\Xi^{-}$
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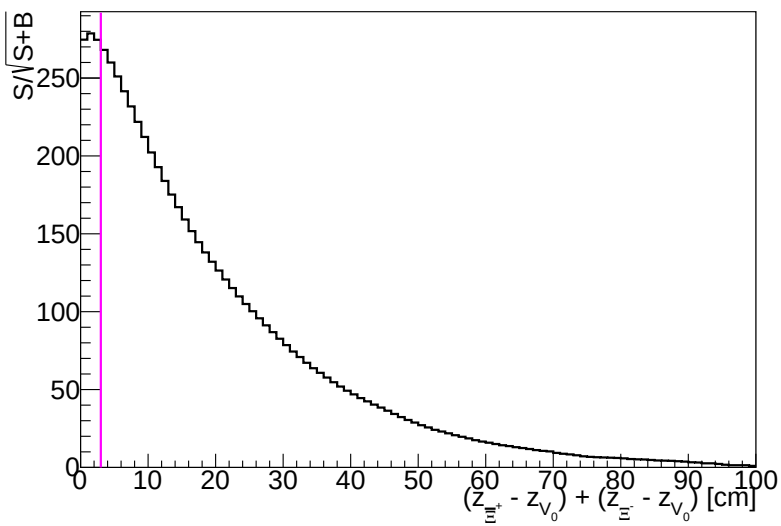
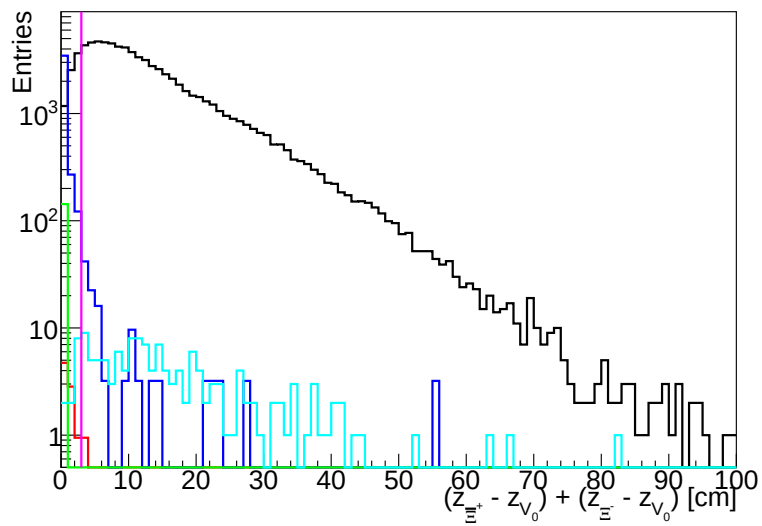




Final Efficiencies at $p_{\mathrm{beam}} = 4.6$ GeV/c

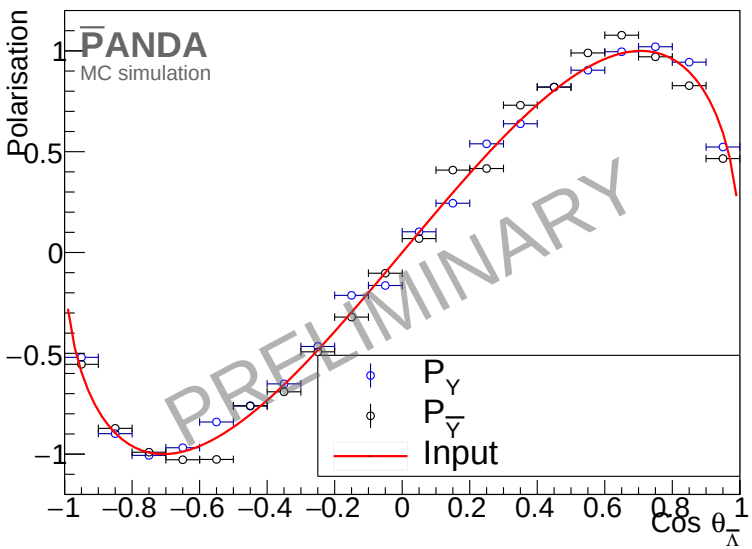
Limits are 90% C.L.

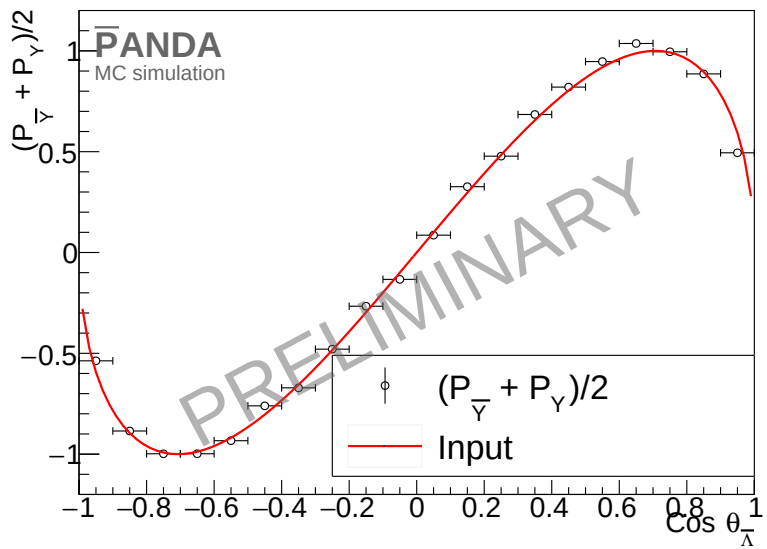
Channel	$\overline{\Xi}^{+}\Xi^{-}$	$\overline{\Sigma}(1385)^{+}\Sigma(1385)^{-}$	$\overline{\Lambda}\Lambda 2\pi^{+}2\pi^{-}$	$\overline{p}p2\pi^{+}2\pi^{-}$	DPM
Sample	8.5×10^5	10×10^7	10×10^7	10×10^7	10×10^7
σ_{eff} [μb]	0.41	4.33	14.7	130	68 800
Weight factor	1	0.946	3.21	28.6	15 087
Preselection 2nd	8.65×10^4	3.29×10^4	2.61×10^4	105	5
Final selection	7.23×10^4	1	39	0	0
N weighted	7.23×10^4	0.9	125	0	0
S/B	527	7.63×10^4	576	$> 1.1 \times 10^3$	> 2.1

- Final signal efficiency of $\epsilon = 8.5\%$, higher than $p_{\mathrm{beam}} = 4.6$ GeV/c case
- High purity, $S/B > 500$ across relevant background channels, purer than $p_{\mathrm{beam}} = 4.6$ GeV/c case

Polarisation P_y at $p_{\mathrm{beam}} = 4.6$ GeV/c

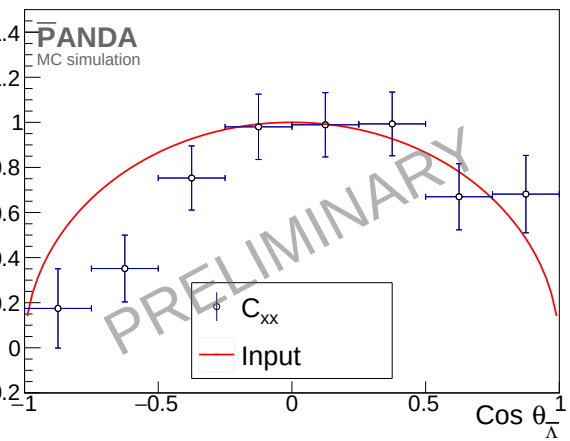
- Simulate sample of 10^7 signal events to construct acceptance correction matrices
- Acceptance correct and extract spin observables with method of moments

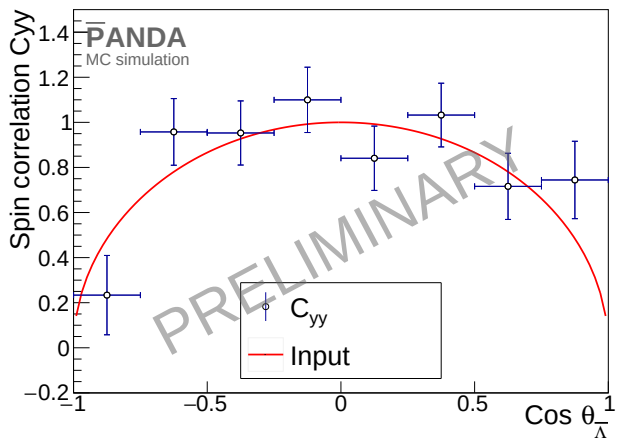


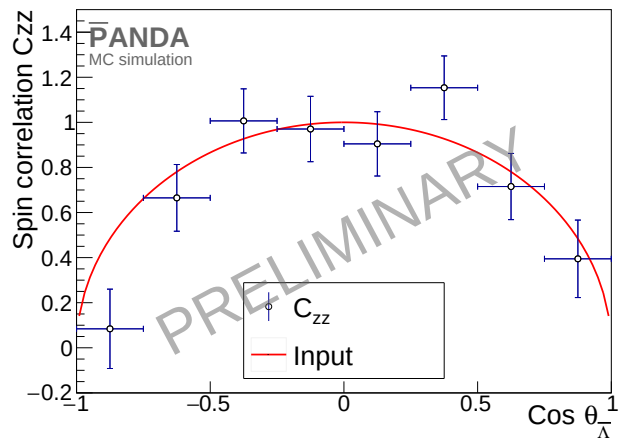


Spin Correlation C_{ii} at $p_{\mathrm{beam}} = 4.6$ GeV/c

- Simulate sample of 10^7 signal events to construct acceptance correction matrices
- Acceptance correct and extract spin observables with method of moments

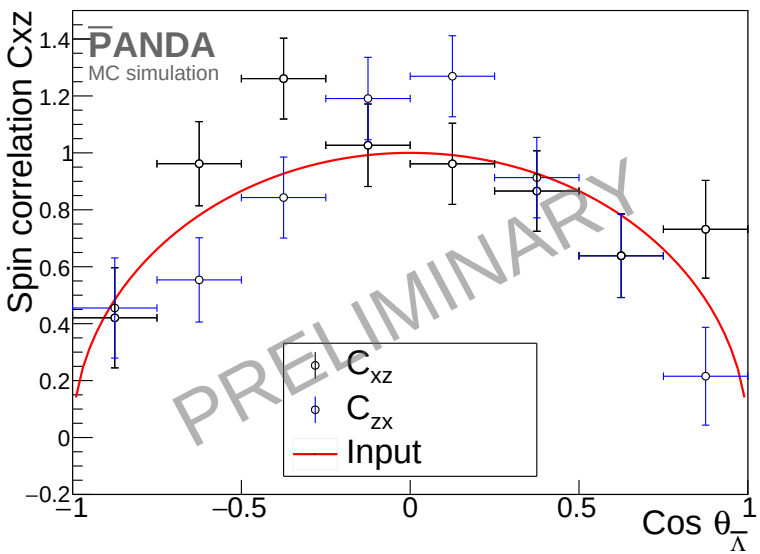


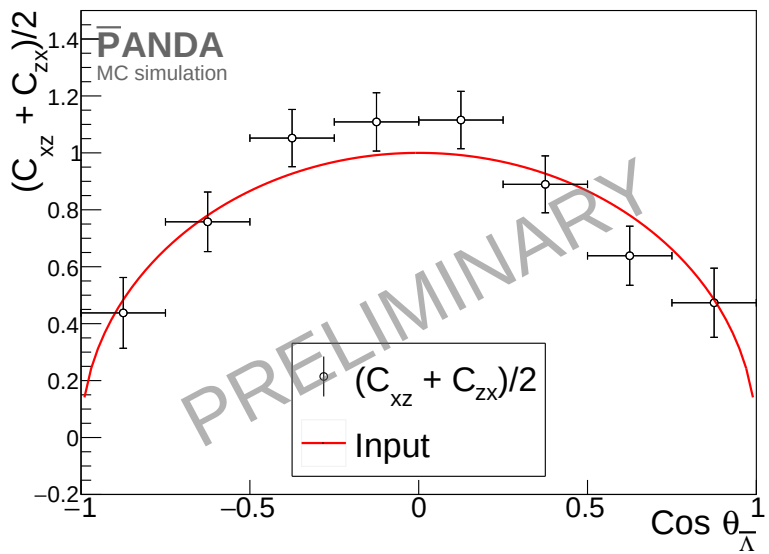




Spin Correlation C_{ij} at $p_{\mathrm{beam}} = 4.6$ GeV/c

- Simulate sample of 10^7 signal events to construct acceptance correction matrices
- Acceptance correct and extract spin observables with method of moments





Summary & Outlook

- Analysis at $p_{\mathrm{beam}} = 7.0$ GeV/c yields a signal efficiency of $\epsilon = 7.9\%$
- Testing two forward peaking distributions yield $\epsilon = 7.5\%$ and $\epsilon = 5.0\%$
- Spin observables analysis also tested at $p_{\mathrm{beam}} = 4.6$ GeV/c
  - Signal efficiency of $\epsilon = 8.5\%$
  - Spin observables can be extracted

Summary & Outlook

- Analysis at $p_{\mathrm{beam}} = 7.0$ GeV/c yields a signal efficiency of $\epsilon = 7.9\%$
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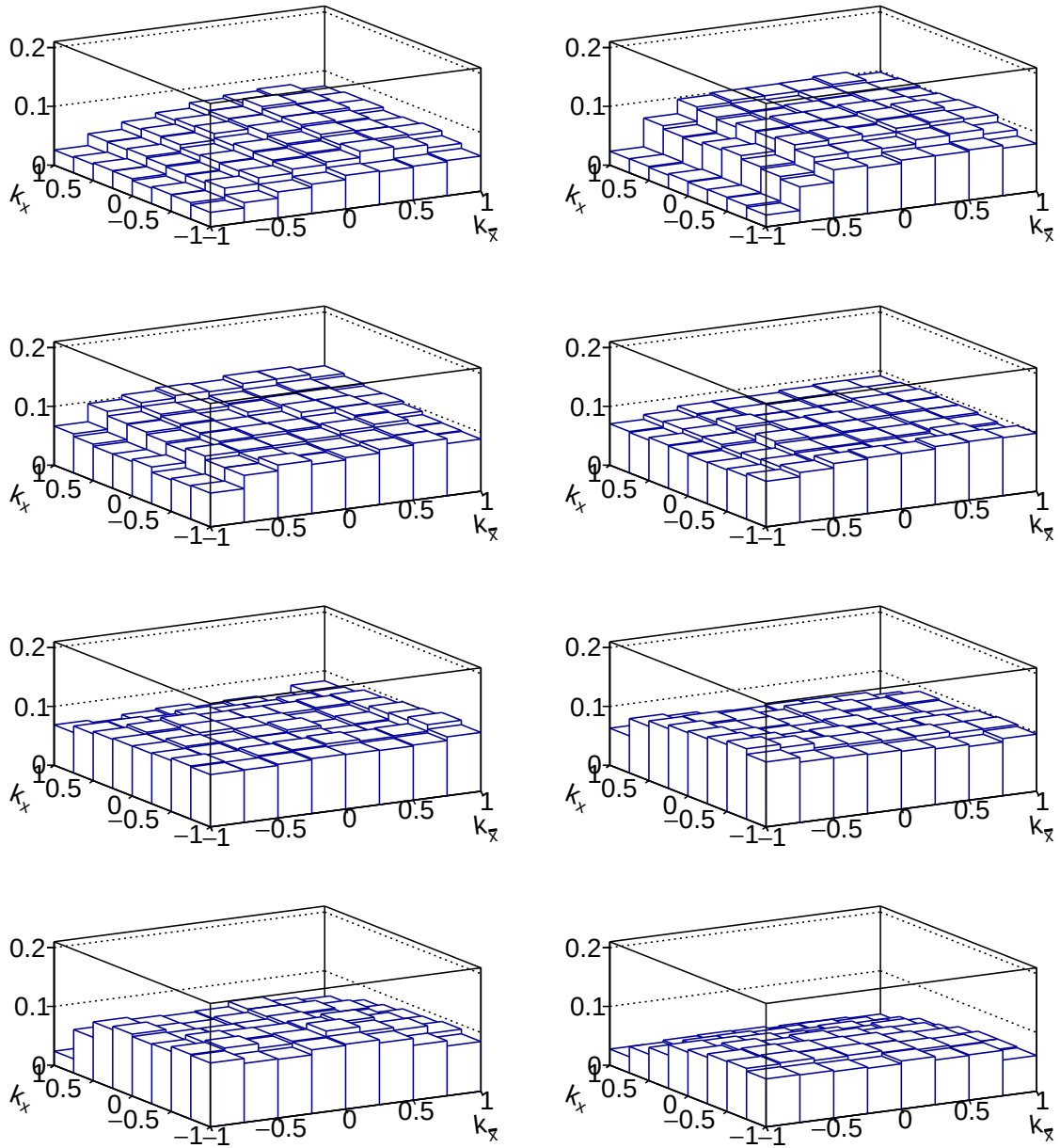
- Spin observables analysis also tested at $p_{\mathrm{beam}} = 4.6$ GeV/c
  - Signal efficiency of $\epsilon = 8.5\%$
  - Spin observables can be extracted

Thank you for your attention!

Backup

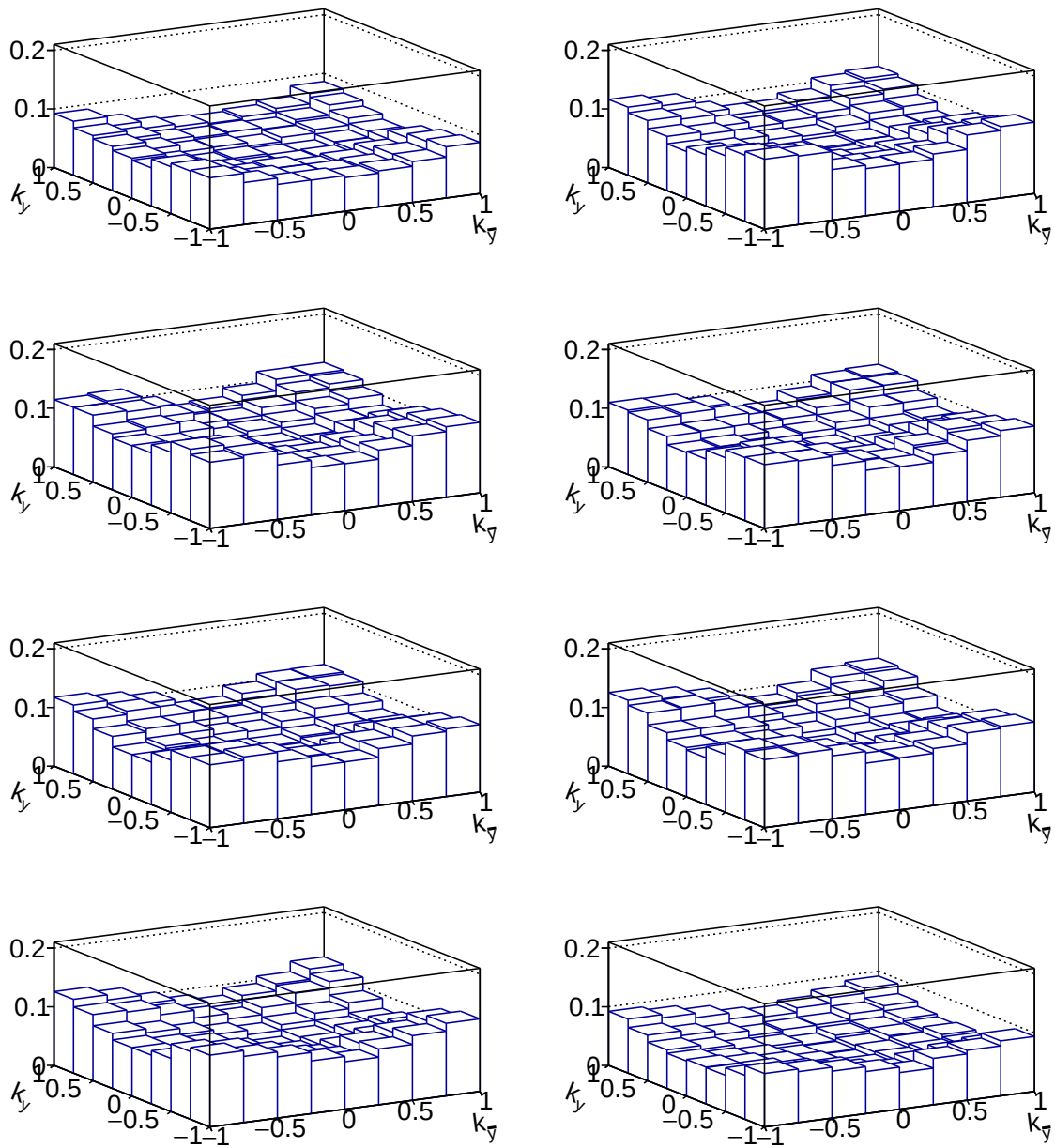
Acceptance functions

Acceptance used for C_{xx}



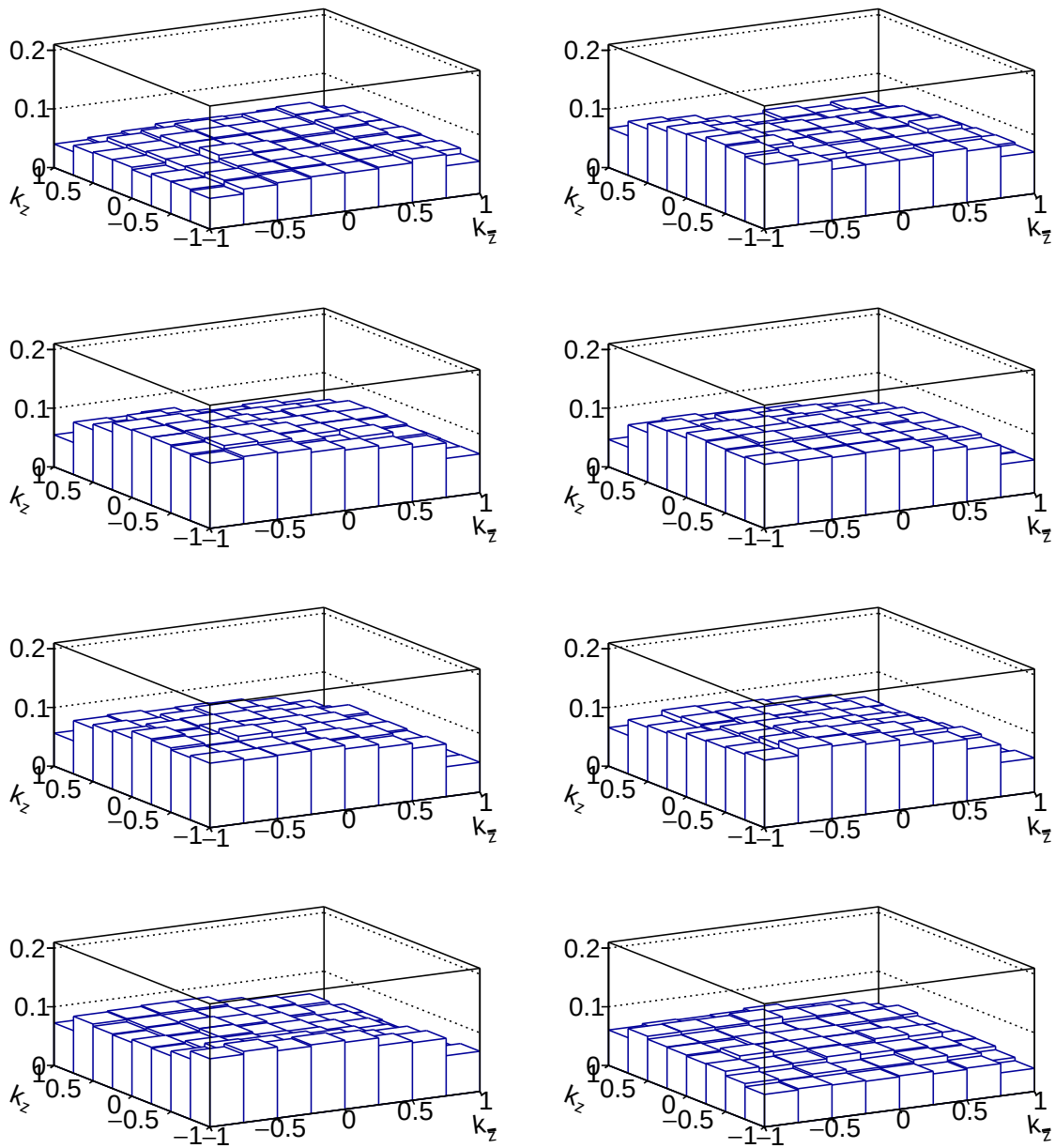
Acceptance functions

Acceptance used for
C_{yy}



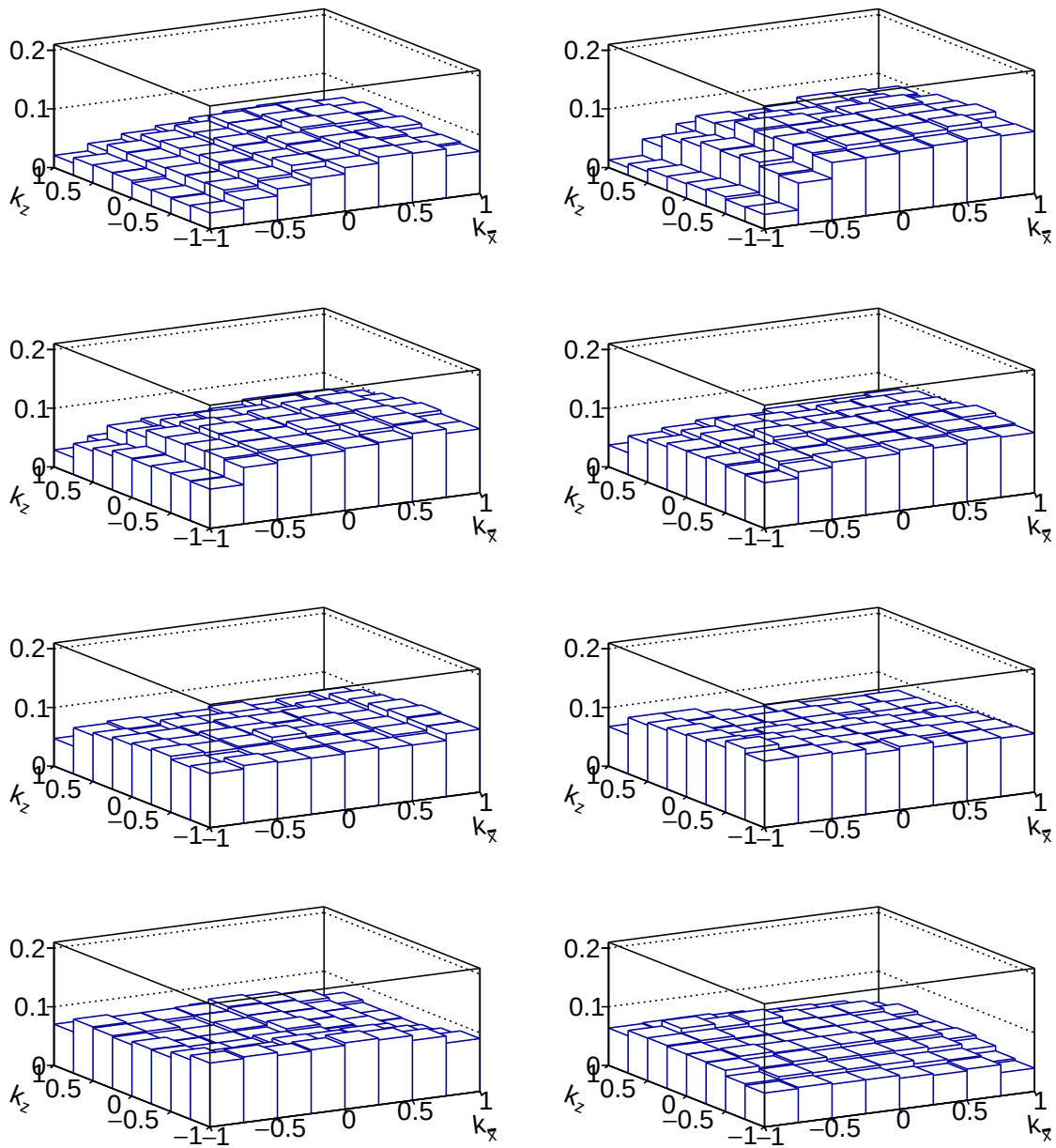
Acceptance functions

Acceptance used for
C_{zz}



Acceptance functions

Acceptance used for
C_{xz}



Acceptance functions

Acceptance used for
C_{zx}