Spin Correlation Measurements in $\overline{p}p \to \overline{\Lambda}\Lambda$ Production

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

PANDA Collaboration Meeting
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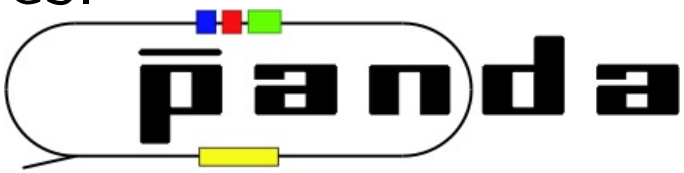
GSI



Reconstructing the Spin Observables

Spin observables can be extracted using Method of Moments:

$$\langle \cos\theta_y \rangle = \langle k_y \rangle = \int_{-1}^{1}\int_{-1}^{1} I(k_y, k_{\overline{y}}) \times k_y \, dk_y \, dk_{\overline{y}}$$

Polarisation and Spin Correlation is given by:

$$P_y = \frac{3}{\alpha}\langle k_y \rangle = \frac{3}{\alpha}\frac{\sum_{m=1}^{N} k_{y,m}}{N}$$

$$C_{ij} = \frac{9}{\overline{\alpha}\alpha}\langle \overline{k}_i k_j \rangle = \frac{9}{\alpha\overline{\alpha}}\frac{\sum_{m=1}^{N} \overline{k}_{i,m} k_{j,m}}{N}$$

Erik Thomé, Elisabetta Perotti, Uppsala University

Reconstructing the Spin Observables

If $\cos\theta_y$ is symmetric around 0 i.e.

$$A_y(\cos\theta_y) = A_y(-\cos\theta_y)$$

$$A_{\overline{y}}(\cos\theta_{\overline{y}}) = A_{\overline{y}}(-\cos\theta_{\overline{y}}),$$

the spin observables are obtainable without acceptance correction:

$$P = \frac{1}{\alpha}\frac{\langle k_y\rangle}{\langle k_y^2\rangle}$$

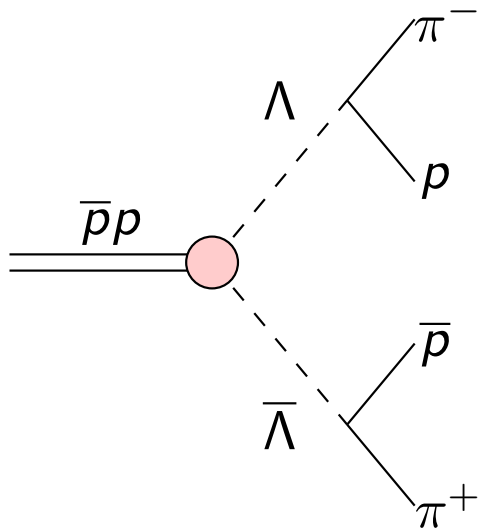
$$C_{yy} = \frac{1}{\alpha\overline{\alpha}}\frac{\langle \overline{k}_y k_y\rangle}{\langle \overline{k}_y^2\rangle\langle k_y^2\rangle}$$

$$C_{ij} = \frac{1}{\alpha\overline{\alpha}}\frac{\langle \overline{k}_i k_j\rangle - \langle \overline{k}_i\rangle\langle k_j\rangle}{\langle \overline{k}_i^2\rangle\langle k_j^2\rangle}, i,j = x,z$$

Simulation parameters

Simulations are done with feb17 release version.

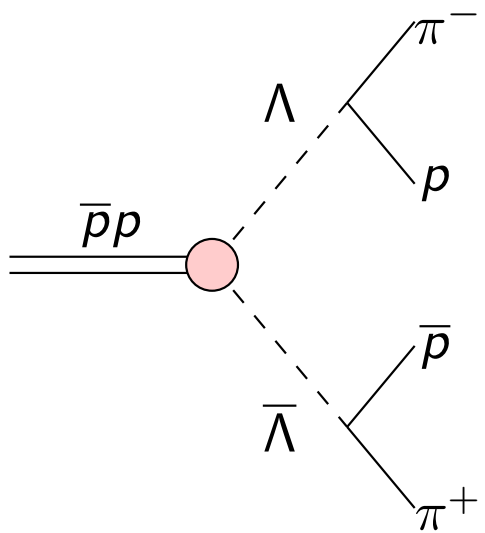
- $\sim 10^6$ $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$ events
- Forward-peaking distribution
- Antiproton beam $p_{\overline{p}} = 1.642$ GeV/c
- Full $\overline{\text{P}}$ANDA Detector setup
- Ideal Pattern Recognition
- Ideal Particle Identification



Event reconstruction

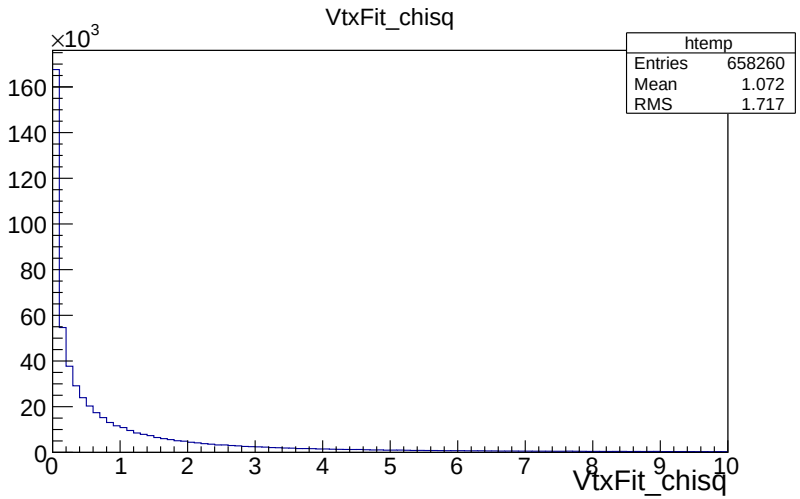
Event selection:

- Combine $p\pi^-$, $\overline{p}\pi^+$
- Select $|m_\Lambda - M(p\pi^-)| < 0.3$ GeV
- Vertex fit on all combinations of $p\pi^-$, $\overline{p}\pi^+$
  Reject a candidate if
  $P(\mathrm{Vtxfit}) < 0.001$
  Select combination with smallest χ^2
- Use variables from vertex fit in a 4C fit over whole decay chain

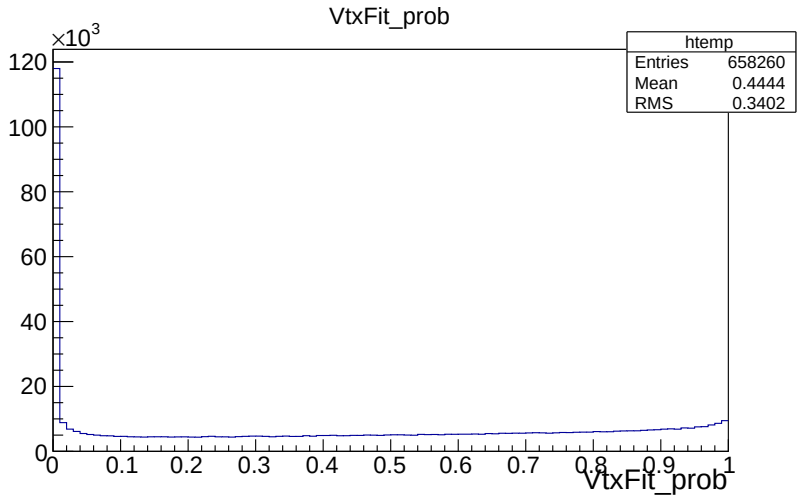


Vertex fit distributions

Lambda vertex fit χ^2



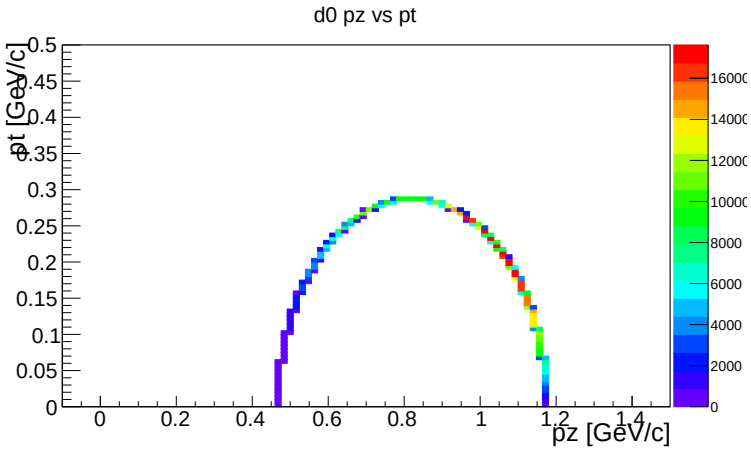
Lambda vertex fit probability



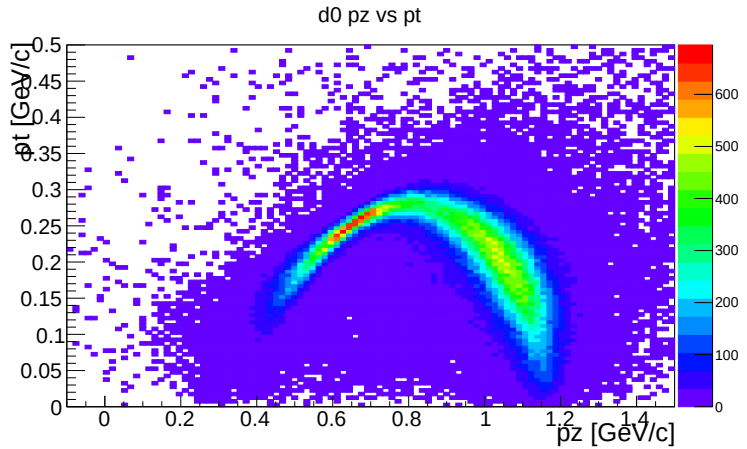
- Probability distribution a little bit shifted toward higher values?

Momentum distribution from vertex fit

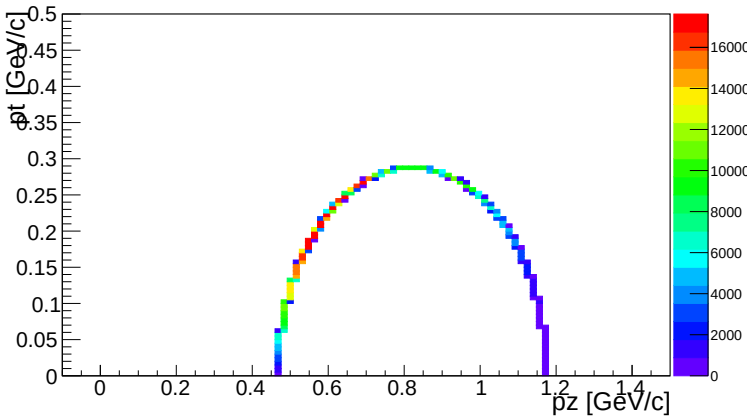
MC Anti-Lambda



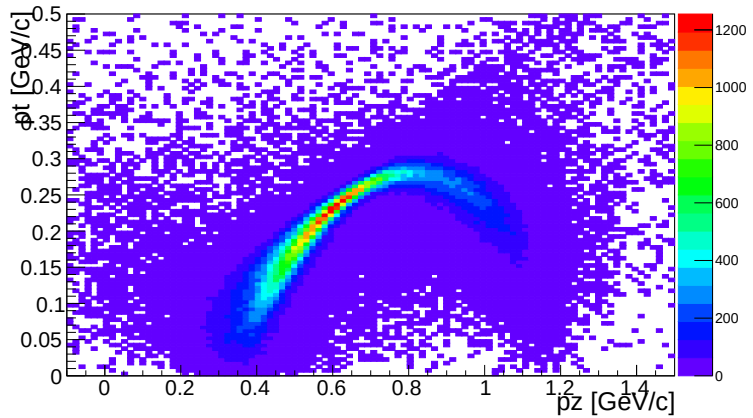
Anti-Lambda



MC Lambda



Lambda



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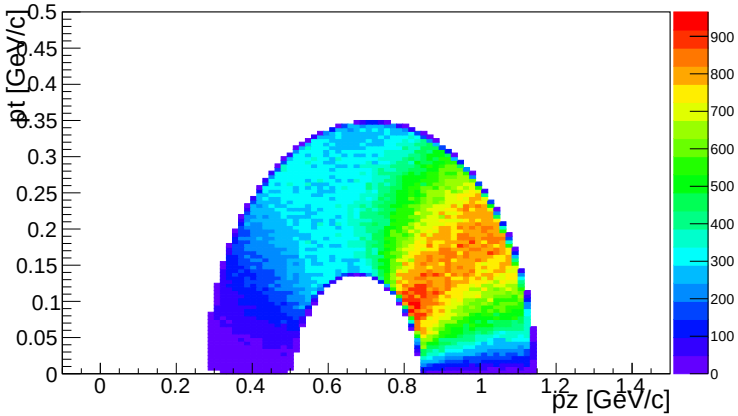
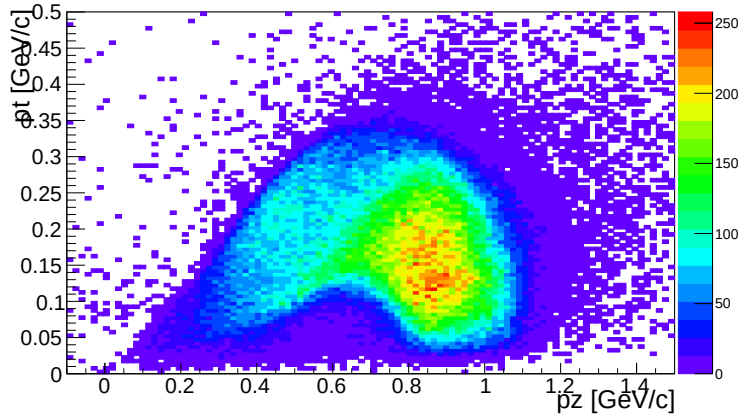


Anti-Proton



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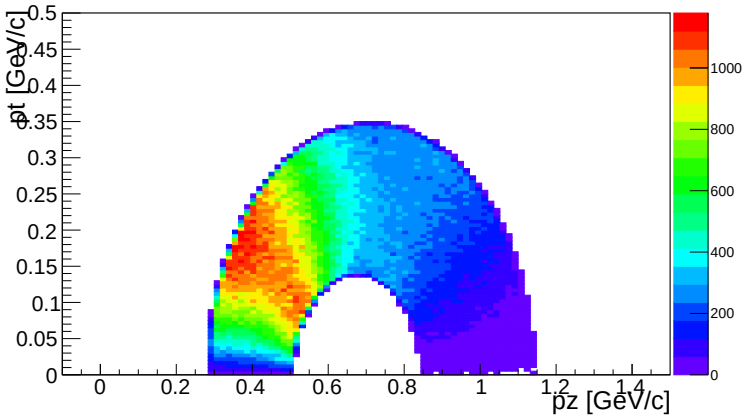
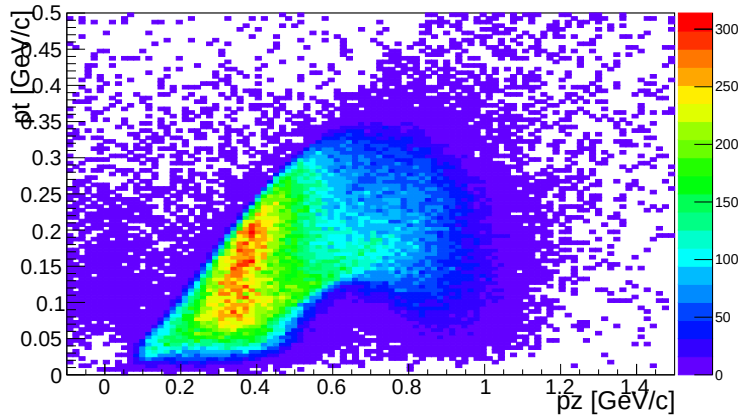


Proton



Momentum distribution from vertex fit

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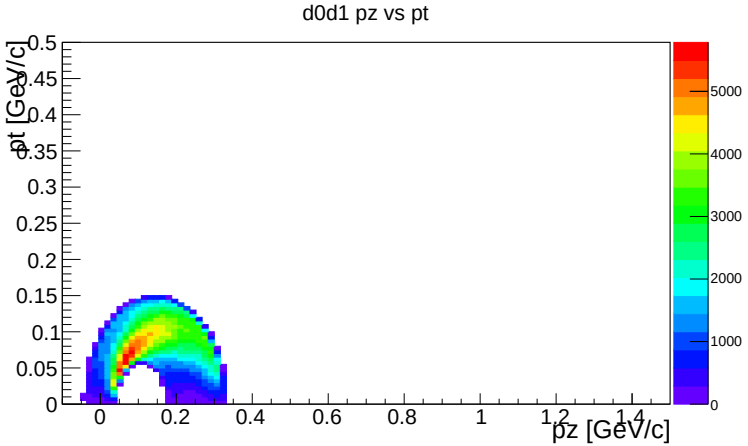
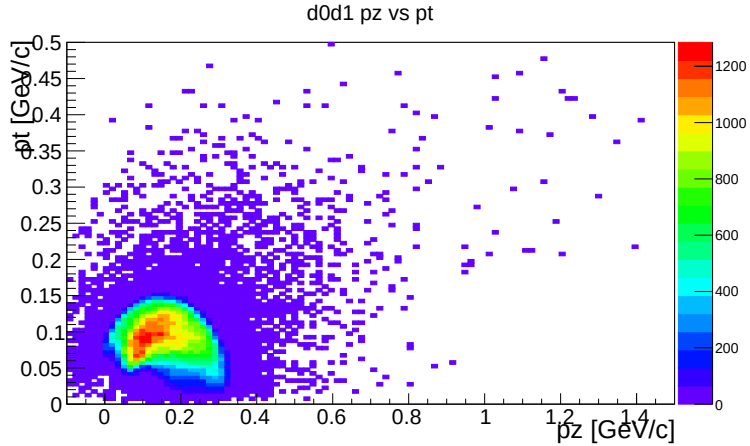
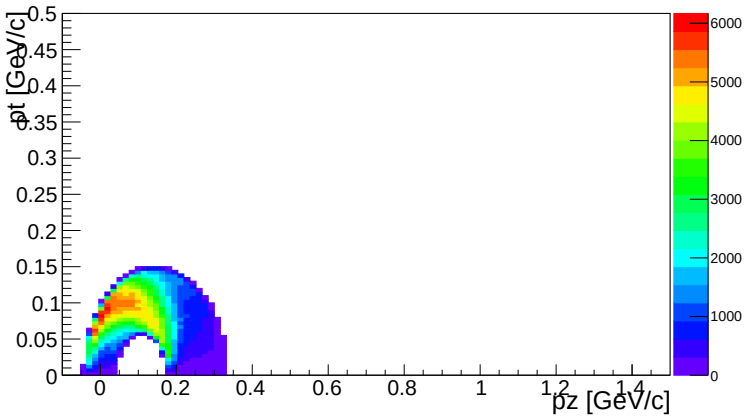


Piplus



MC Piminus



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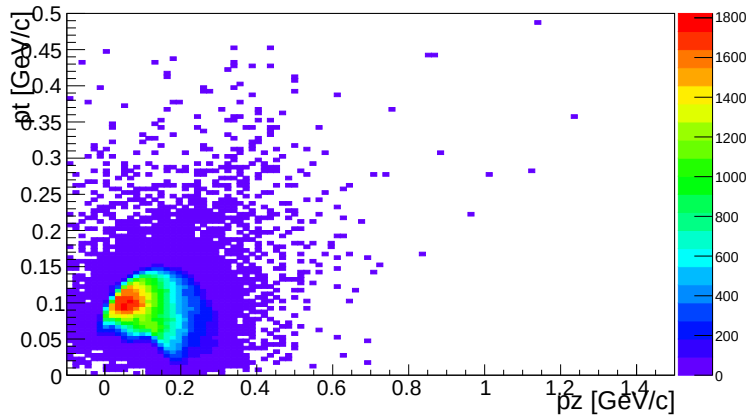
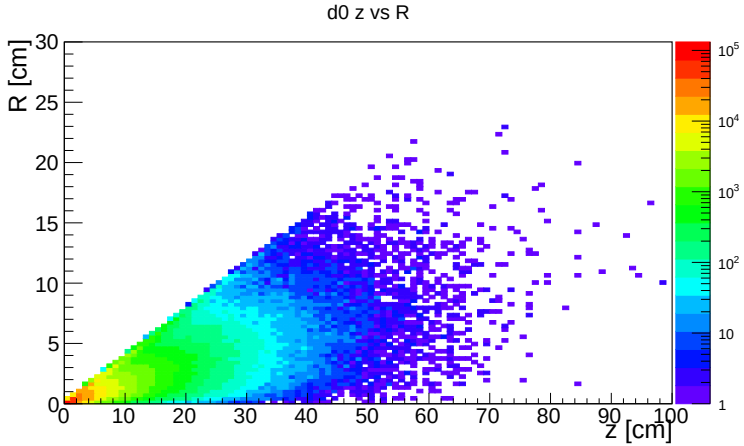
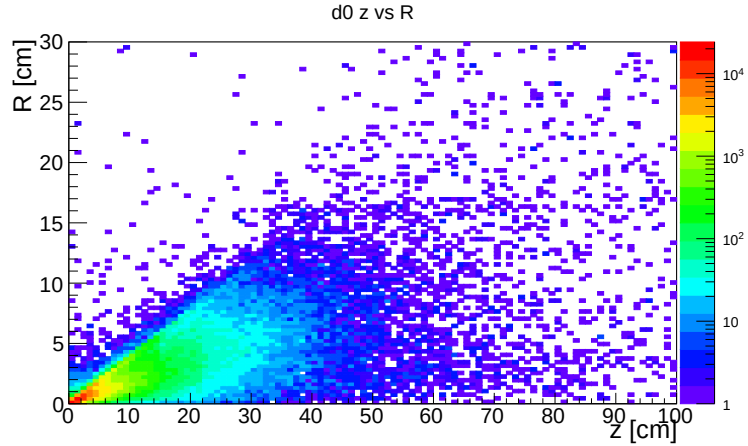


Vertex position distribution from vertex fit

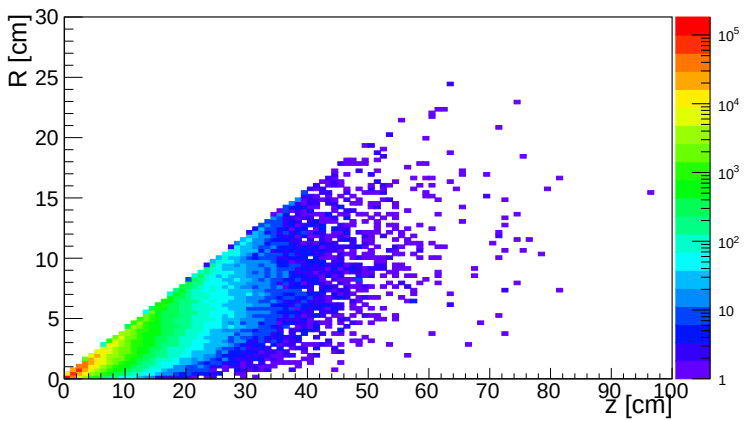
MC Anti-Lambda



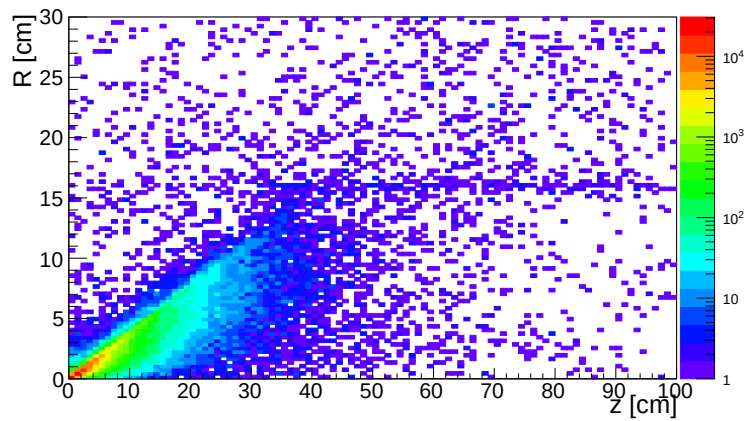
Anti-Lambda



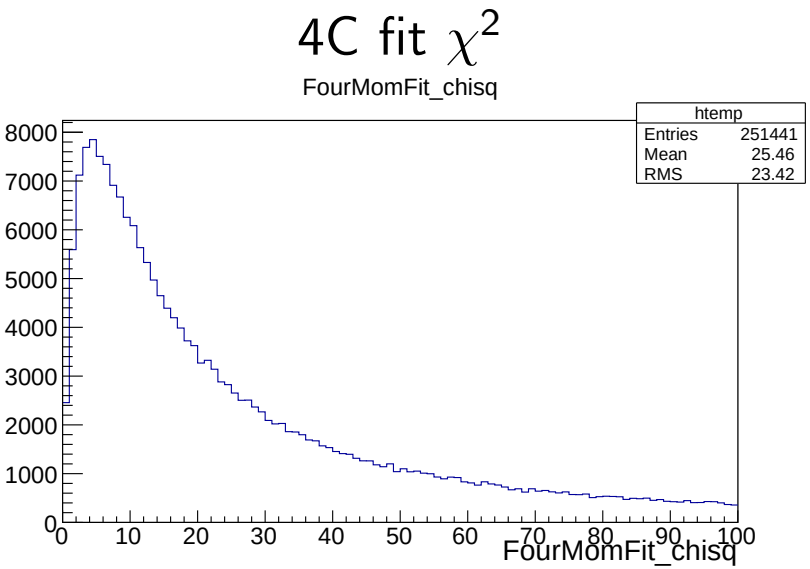
MC Lambda

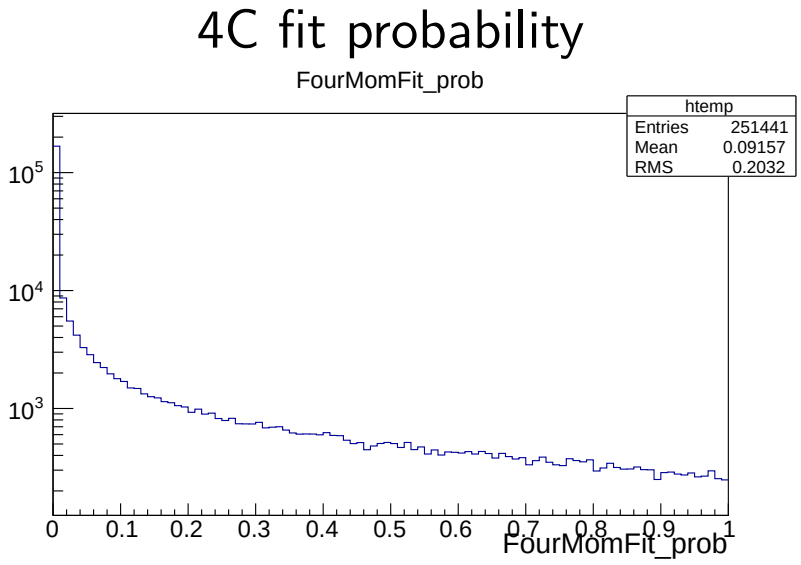


Lambda



4C fit distributions

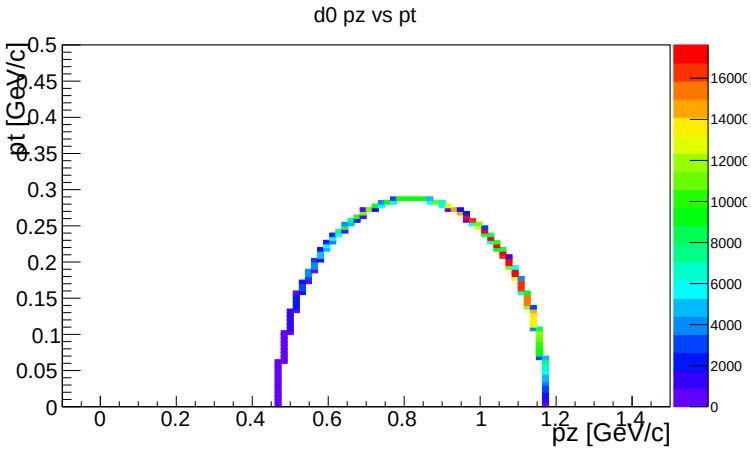




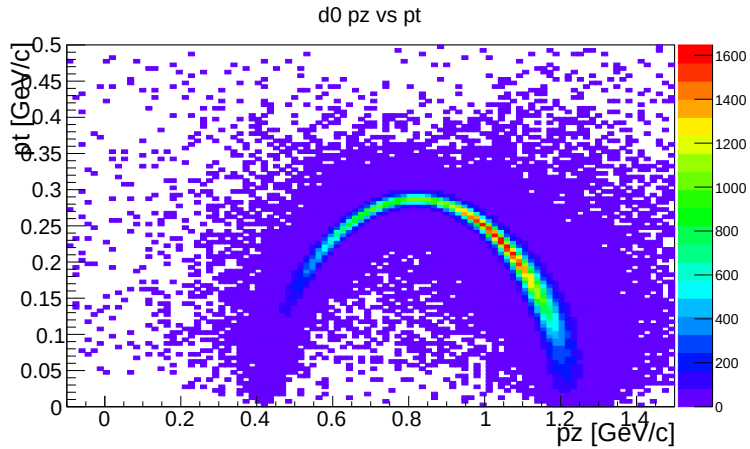
- χ^2 distribution much broader than expected for NDF $= 4$
- Probability distribution a little bit shifted toward lower values?
- Test the fix for the RhoFitters made by Xinying Song!

Momentum distribution from 4C fit

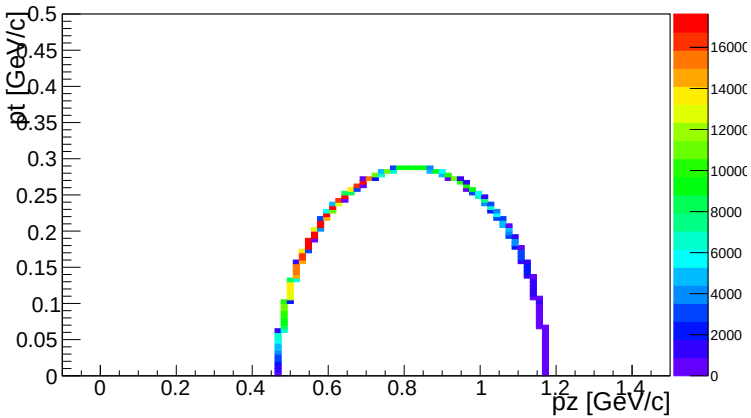
MC Anti-Lambda



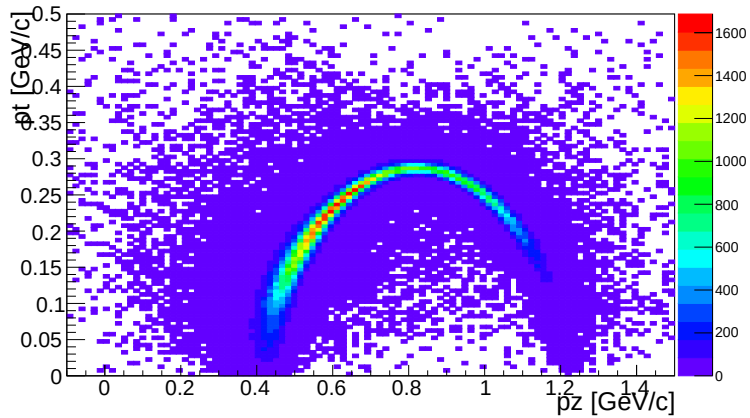
4Cfit Anti-Lambda



MC Lambda



4Cfit Lambda



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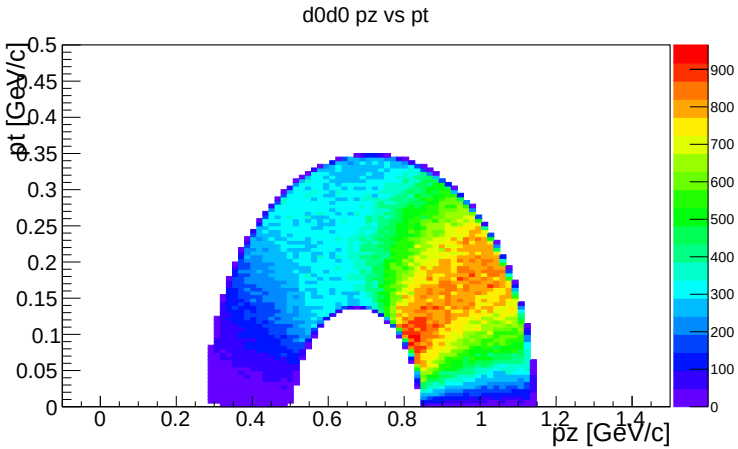
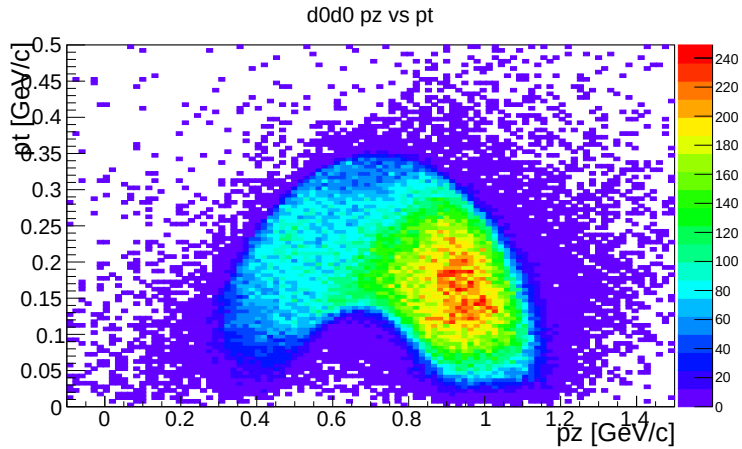


4Cfit Anti-Proton



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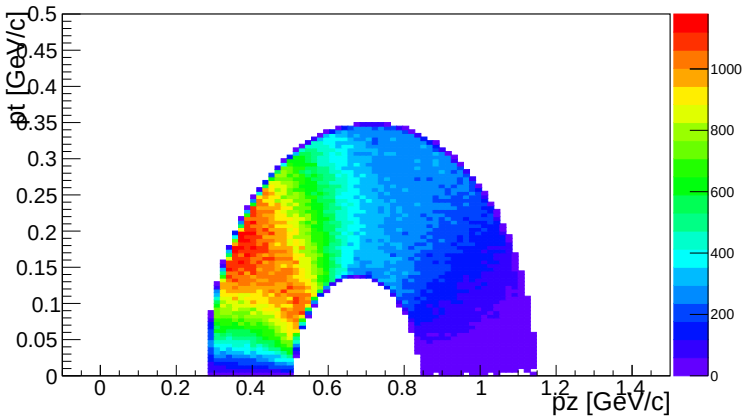

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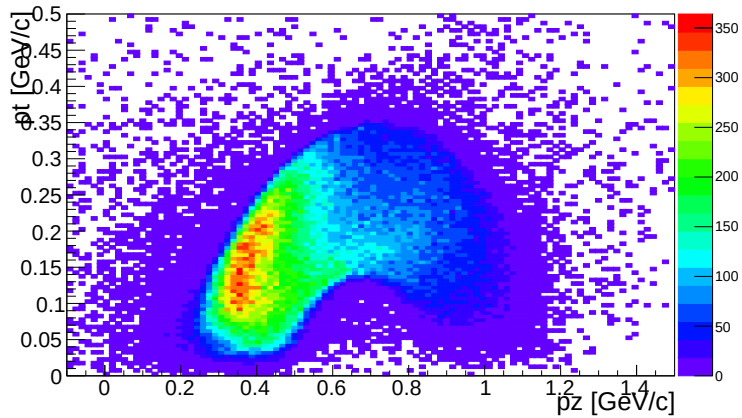

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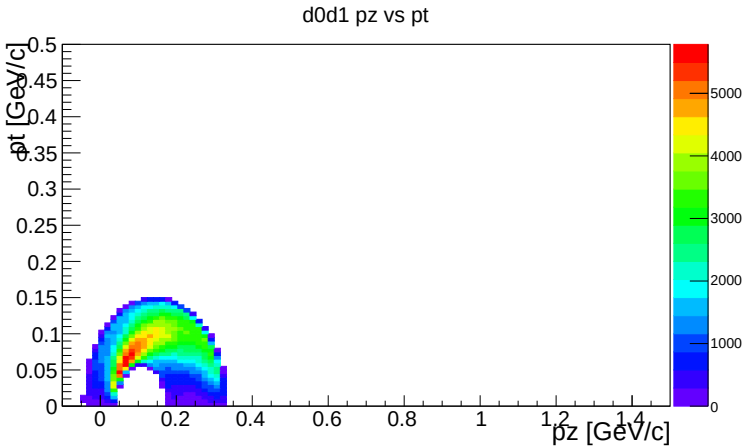

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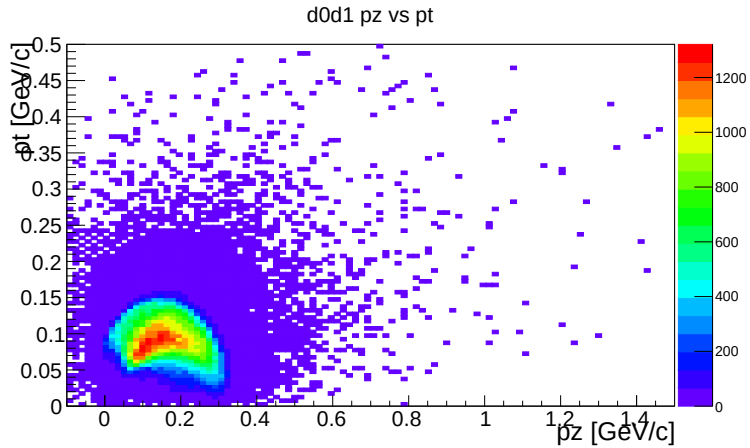

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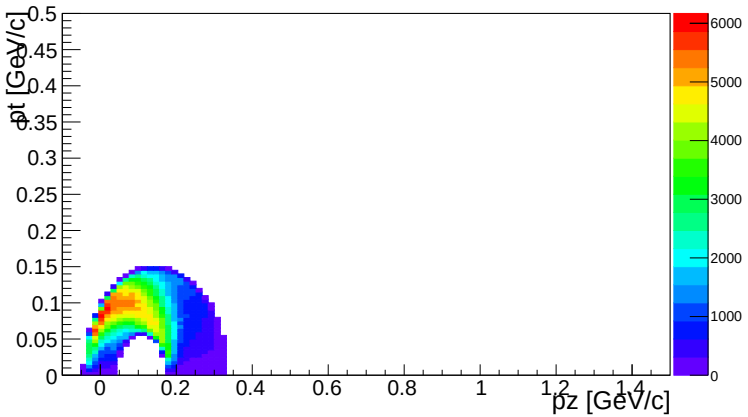

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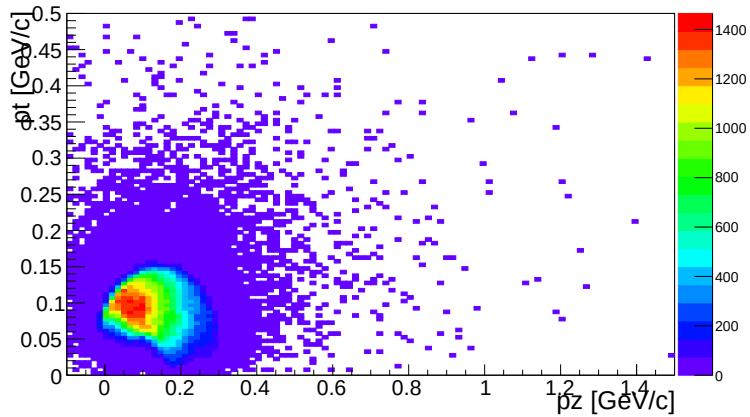
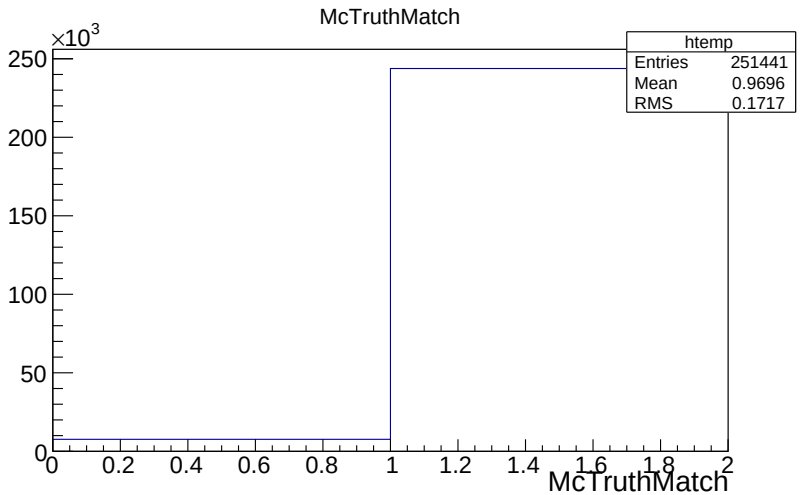


Monte Carlo truth matching



- Out of $\approx 10^6$ events, $\approx 2.5 \times 10^5$ $\overline{p}p$ systems reconstructed
- 7648 $\overline{p}p$ systems with at least 1 incorrectly assigned particle
- Combinatorial background: 3%

Generating Spin Observables sample

How to generate $\overline{p}p \to \overline{\Lambda}\Lambda$ sample:

- Simulate $\Lambda \to p\pi^-$, $\overline{\Lambda} \to \overline{p}\pi^+$ with flat phase space
- Use input polarisation
$$C_{ij} = \sin\theta_\Lambda$$
- Evaluate
$$w_m = 1 + \overline{\alpha}\alpha C_{ij}\overline{k}_{i,m}k_{j,m},$$
assign as weight to each event

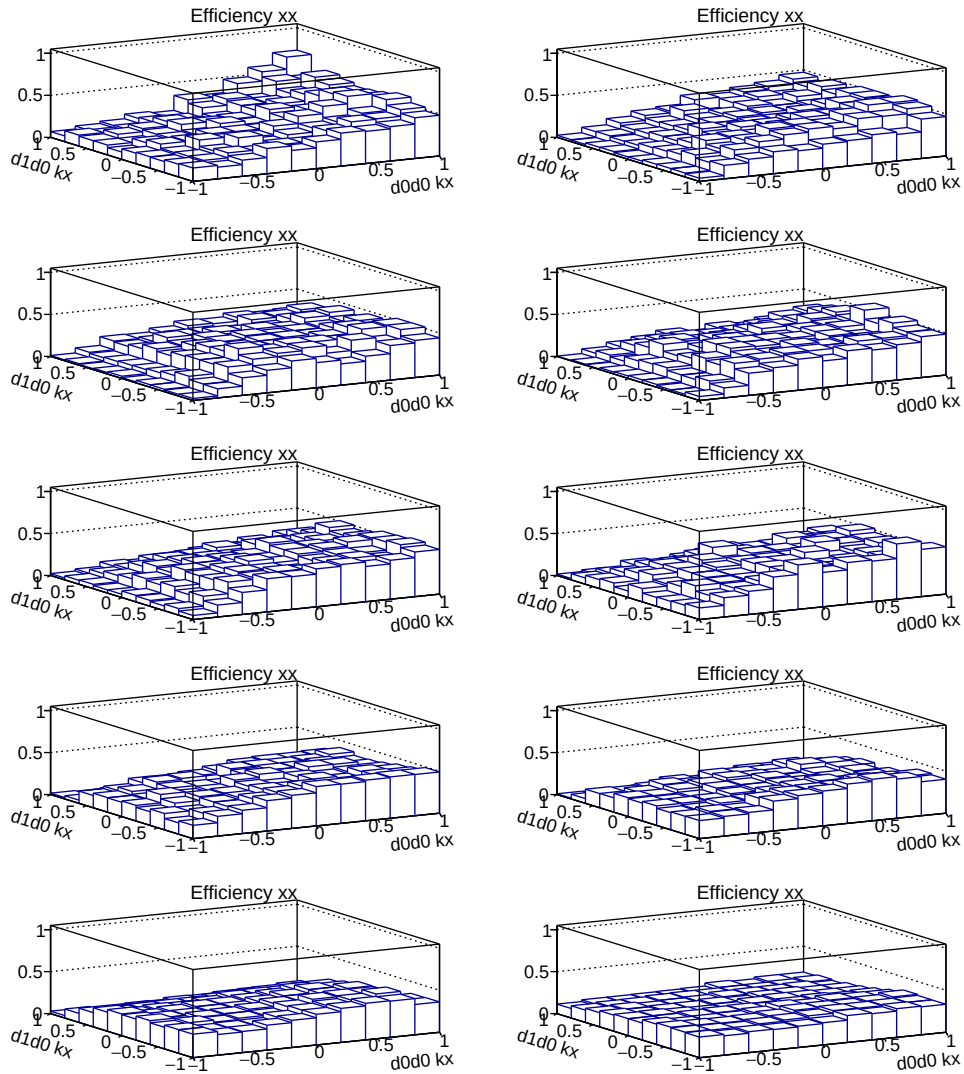
Spin correlation is reconstructed according to

$$C_{ij} = \frac{9}{\overline{\alpha}\alpha}\frac{\sum_m \frac{w_m}{A(k_{y,m})}\overline{k}_{i,m}k_{j,m}}{\sum_m \frac{w_m}{A(k_{y,m})}}$$

Acceptance functions

Acceptance used for C_{xx}

- Using variables from vertex fit
- Should use 4C variables in the future!
- Top left:
  $-1 < \cos\theta^{*}_{\overline{\Lambda}} < -0.8$
  Top right:
  $-0.8 < \cos\theta^{*}_{\overline{\Lambda}} < -0.6$
  and so on...



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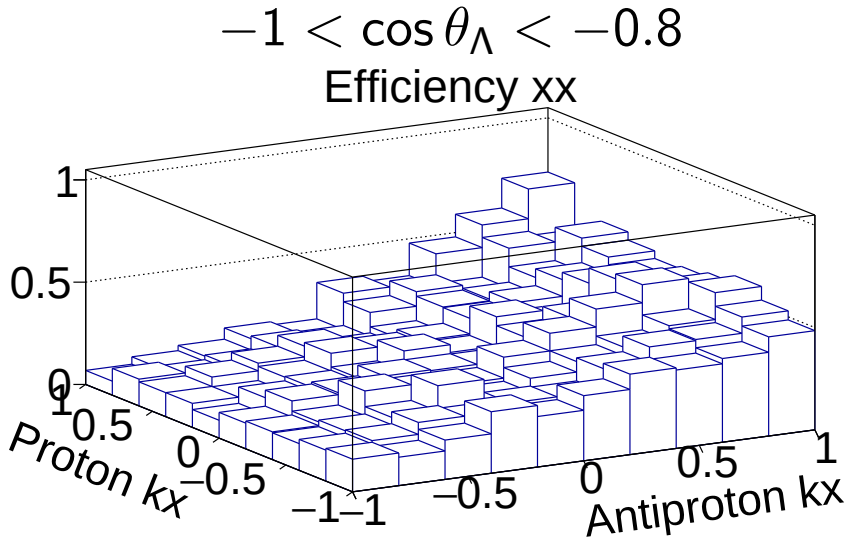

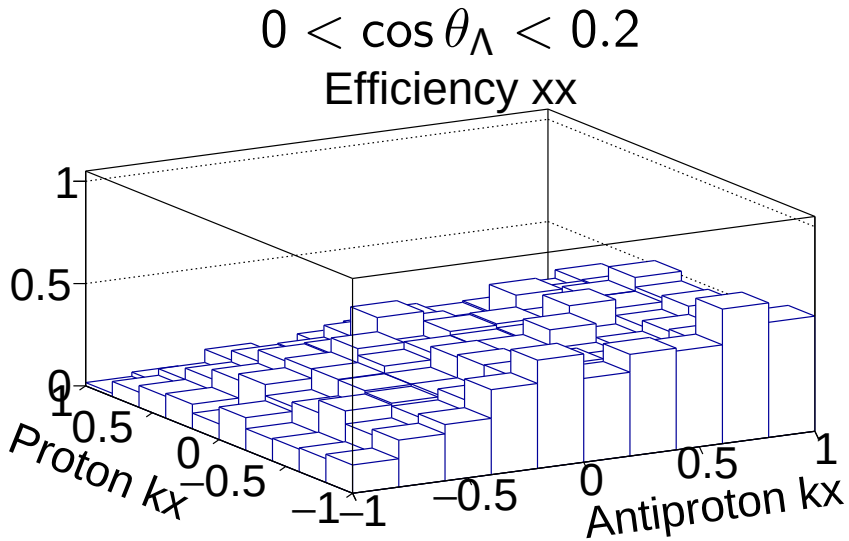

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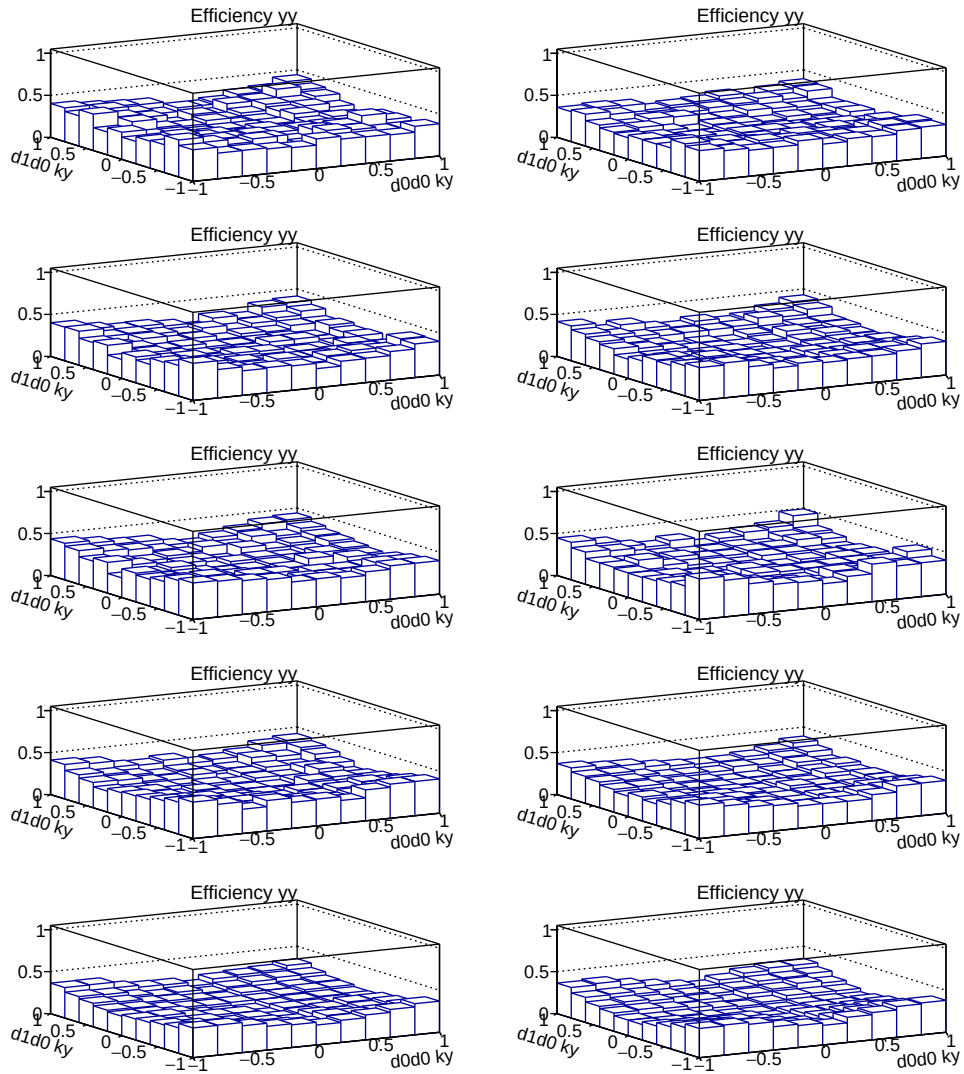
- Looks symmetric, can extract C_{ij} without acceptance function
- Quantify degree of symmetry?



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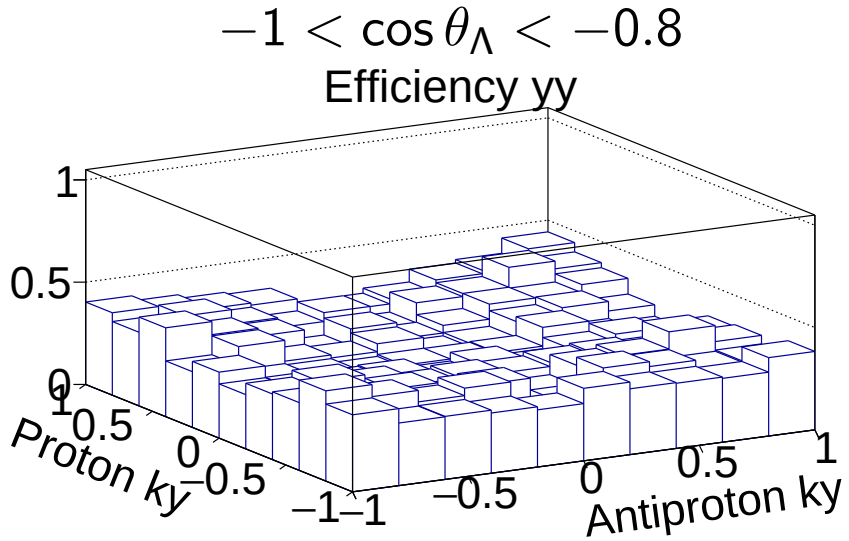
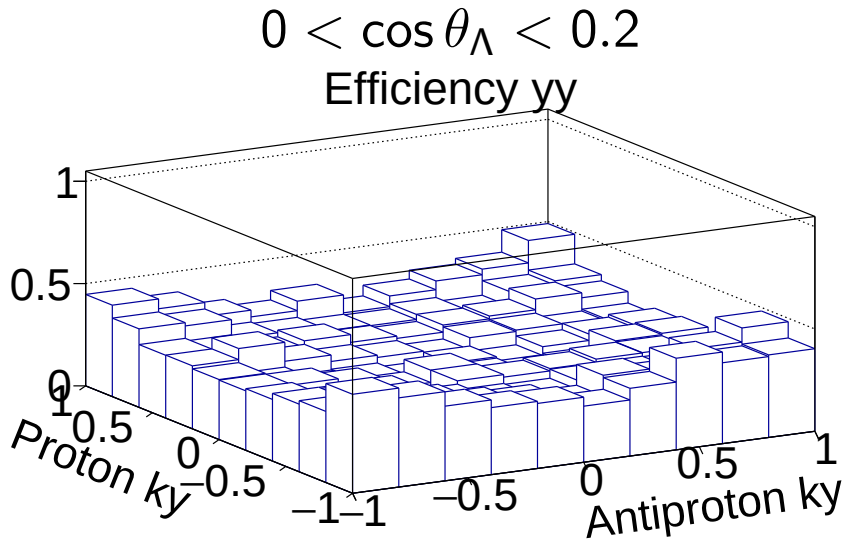
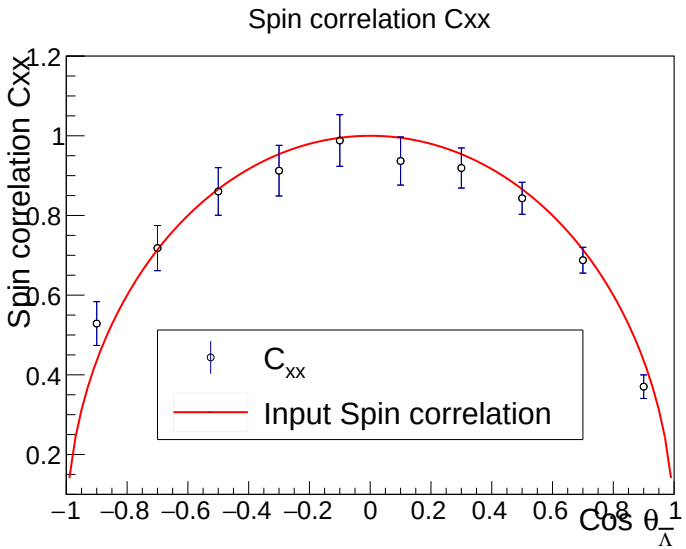
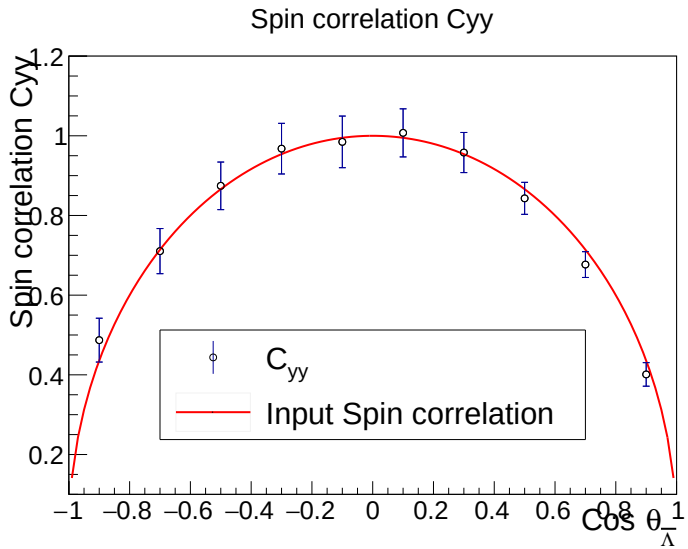




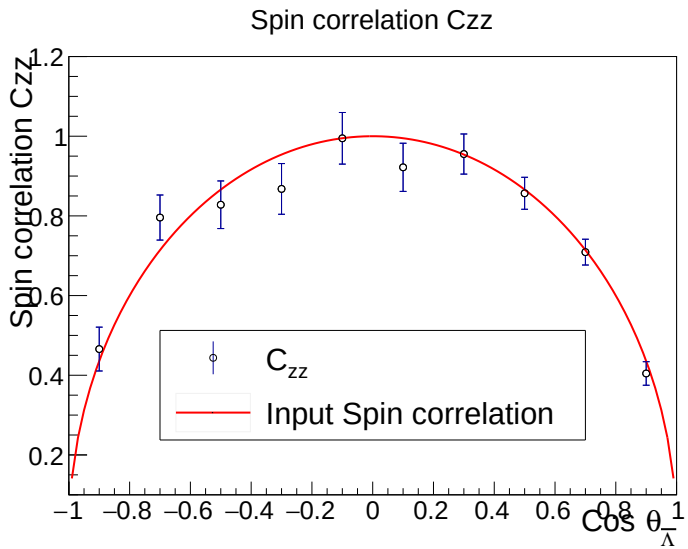
Spin Correlation C_{ii}



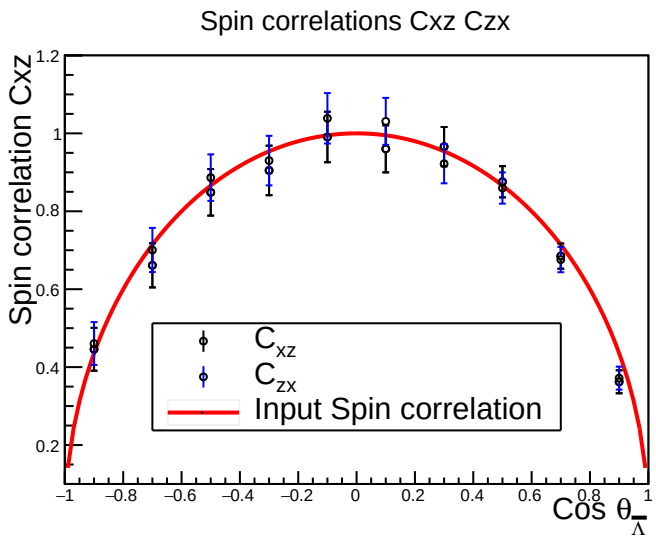


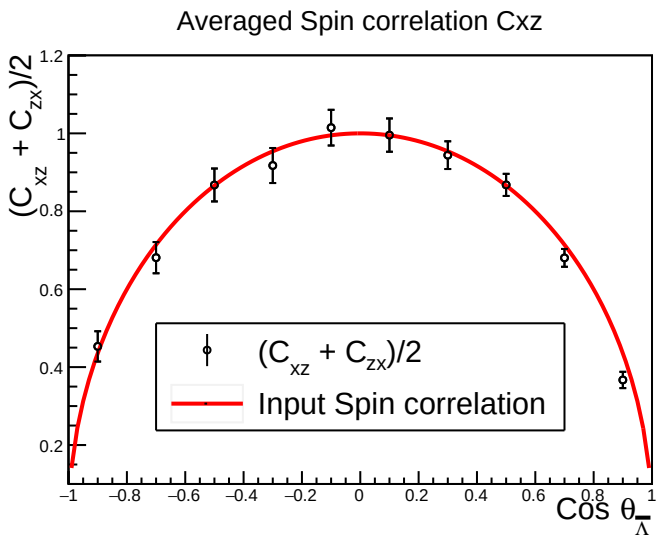
Spin correlation error given by

$$\sigma_{C_{ij}} = \frac{9}{\overline{\alpha}\alpha}\sqrt{\frac{1}{N-1}\left(\langle \overline{k_i^2} k_j^2 \rangle - \langle \overline{k}_i k_j \rangle^2\right)}$$



Spin Correlation C_{ij}





- From charge conjugation argument, $C_{xz} = C_{zx}$
- Calculate the average of both measurement in each bin for smaller statistical errors

Outlook

- Implement fixes to RhoFitters introduced by Xinying Song
- DecayTreeFitter as alternative
- Change from ideal to realistic PID/no PID
- Background studies (DPM and $\overline{p}p\pi^+\pi^-$)
- Prepare analysis memo

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Thank you for your attention!

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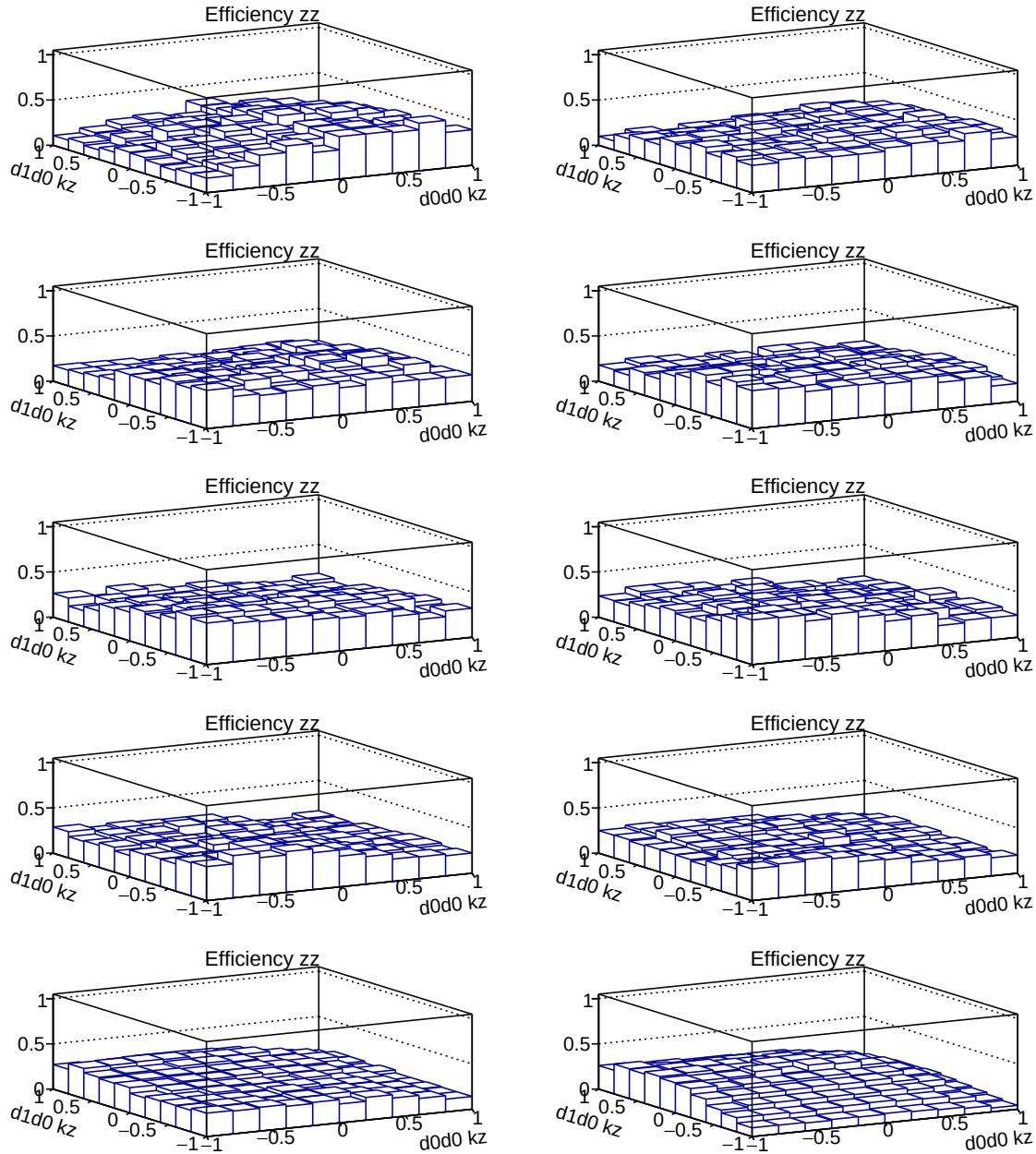
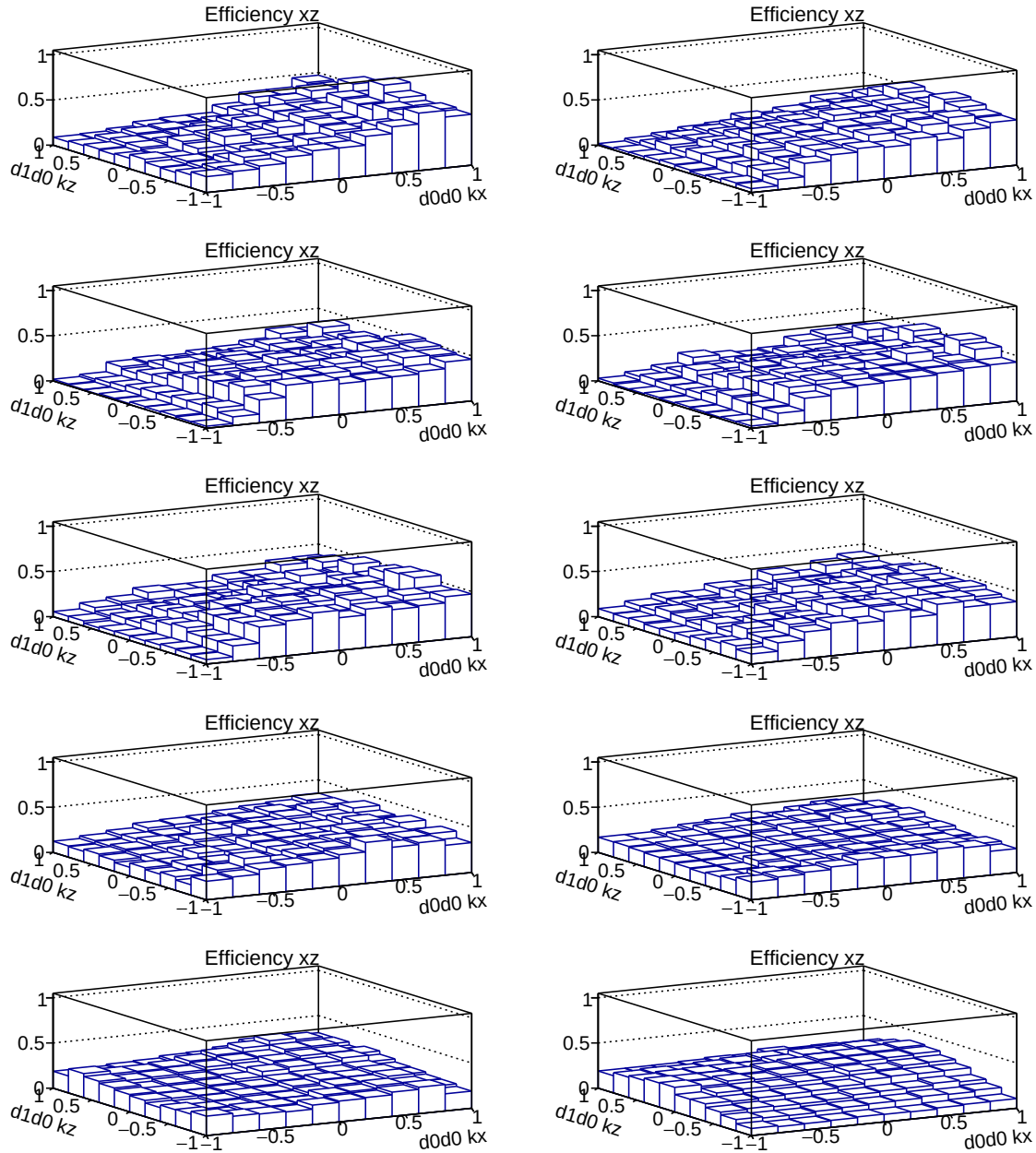
C_{zz}



Acceptance functions

Acceptance used for
C_{xz}



Acceptance functions

Acceptance used for
C_{zx}