Status of the SttCellTrackFinder

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

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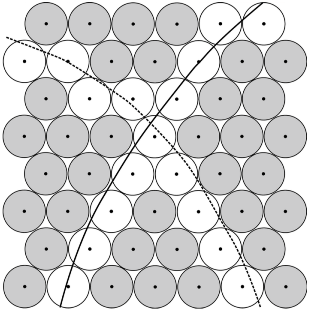
GSI

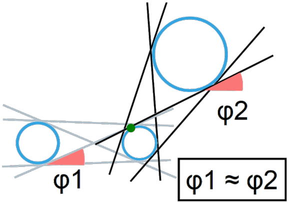
SttCellTrackFinder

Track reconstruction algorithm using only STT.
(J. Schumann, Forschungszentrum Jülich)

1. Cluster hits in parallel straws into tracklets (Cellular Automaton)
2. Refined circle fit using isochrones

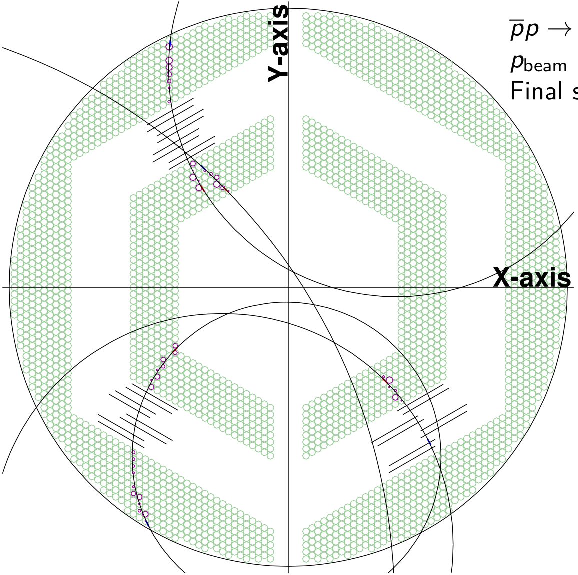


Output: circle for each track in *xy*-plane



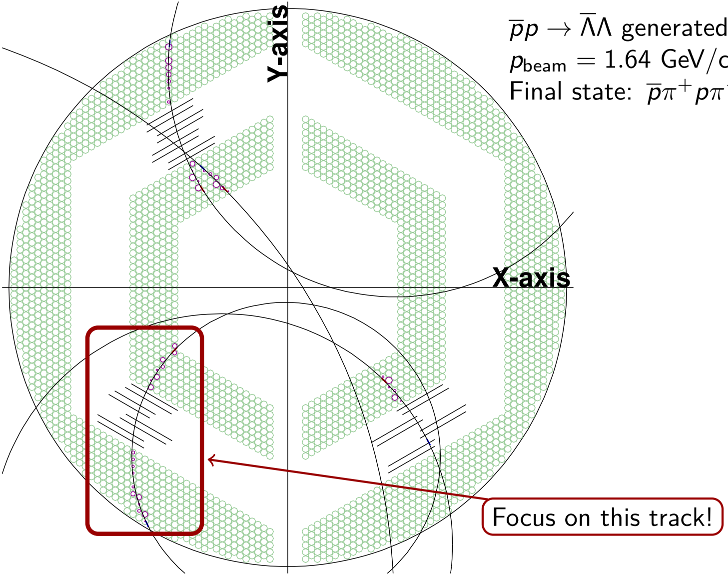
Must include skewed straws to reconstruct p_z

Longitudinal position from skewed straws



$\overline{p}p \rightarrow \overline{\Lambda}\Lambda$ generated at
$p_{\text{beam}} = 1.64$ GeV/c
Final state: $\overline{p}\pi^{+}p\pi^{-}$

Longitudinal position from skewed straws



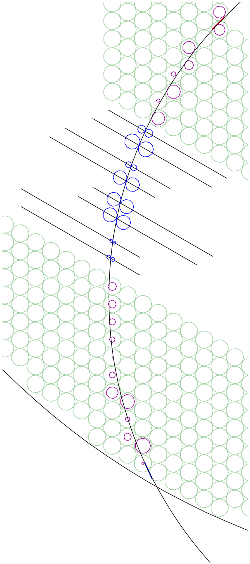
$\overline{p}p \to \overline{\Lambda}\Lambda$ generated at
$p_{\text{beam}} = 1.64$ GeV/c
Final state: $\overline{p}\pi^+ p\pi^-$

Longitudinal position from skewed straws

The method:

1. Extract isochrone radius in skewed straw
2. Center of isochrone gives $z-$position
3. Generate all possible isochrone positions
4. Calculate (z, ϕ)

Ambiguity: Each straw gives two possible (z, ϕ)



Solve ambiguity

Use Hough transform or combinatoric method to reject fake positions

PzFinder - Code structure

- PndSttSkewStrawPzFinderTask.cxx
  - PndTrack - Standard $\overline{\text{P}}$ANDA track object
  - PndTrackCand - PndSttHits belonging to track
  - PndRiemannTrack - Riemann circle parameters to track
- PndSttSkewStrawPzFinder.cxx
  - MoveSkewedHitstoCircle
    - Calculates all possible (z, ϕ) in skewed straw
  - HoughTrueIsoFinder
    - Fills accumulator space, find maximum, rejects fake hits with POCA
  - LineCombiIsoFinder
    - Generates lines, calculates angles, find best path
  - PzLineFitExtract
    - Simple line fit to true (z, ϕ) hits and extracts helix angle
- PndSttSkewStrawPzFinderAnaTask.cxx
  - Task for analysing and drawing output

Reconstruction macro

```
PndSttCellTrackFinderTask *TrackFinder = new PndSttCellTrackFinderTask();
TrackFinder->SetPersistence(kTRUE);
TrackFinder->SetAnalyseSteps(kTRUE);
TrackFinder->SetVerbose(0);
fRun->AddTask(TrackFinder);

PndSttSkewStrawPzFinderTask *PzFinder = new PndSttSkewStrawPzFinderTask();
PzFinder->StoreData(kTRUE);
fRun->AddTask(PzFinder);

PndSttSkewStrawPzFinderAnalysisTask *PzAna = new
     PndSttSkewStrawPzFinderAnalysisTask();
fRun->AddTask(PzAna);

PndMCTrackAssociator* trackMC = new PndMCTrackAssociator();
trackMC->SetTrackInBranchName("FinalTrack");
trackMC->SetTrackOutBranchName("SttMvdGemTrackID");
trackMC->SetPersistence(kFALSE);
fRun->AddTask(trackMC);

PndRecoKalmanTask* recoKalman = new PndRecoKalmanTask();
recoKalman->SetTrackInBranchName("FinalTrack");
recoKalman->SetTrackInIDBranchName("SttMvdGemTrackID");
recoKalman->SetTrackOutBranchName("SttMvdGemGenTrack");
recoKalman->SetBusyCut(50); // CHECK to be tuned
recoKalman->SetTrackRep(0); // 0 Geane (default), 1 RK
recoKalman->SetPropagateToIP(kFALSE);
fRun->AddTask(recoKalman);
```

$z - \phi$ Fit dependence on Circle Fit

The $z - \phi$ fit depends on the circle parameters produced by the SttCellTrackFinder:

- Alignment of isochrones in skewed straws to extract (z, ϕ)

Benchmarking SttCellTrackFinder

- Clusterisation
  How well does the Cellular automaton bunch together STT hits?
- Circle fit
  How good is the transversal momentum resolution?

*All simulations done with full PANDA setup

Tracking Quality Assurance

Tested channels:

- $\overline{\Lambda}\Lambda \to p\pi^- \overline{p}\pi^+$
  @ 1.64 GeV/c
- $\overline{\Lambda}\Lambda \to p\pi^- \overline{p}\pi^+$
  @ 4.0 GeV/c
- $\overline{\Omega}\Omega \to K^- p\pi^- K^+ \overline{p}\pi^+$
  PHSP @ 12.0 GeV/c
- Box generator: π^-,
  $p = 0.5$ GeV
- Box generator: p,
  $p = 0.5$ GeV
- Box generator: π^-,
  $p = 2$ GeV

Tools used:

Ideal TrackFinder:

```
PndMCIdealTrackFinderNewLinks* idealTracking
      = new PndMCIdealTrackFinderNewLinks()
      ;
idealTracking->AddBranchName("MVDHitsPixel")
      ;
idealTracking->AddBranchName("MVDHitsStrip")
      ;
idealTracking->AddBranchName("STTHit");
idealTracking->AddBranchName("GEMHit");
fRun->AddTask(idealTracking);
```

Modified TrackingQA:

```
PndTrackingQualityTaskNewLinks* trackingQA =
      new PndTrackingQualityTaskNewLinks("
     FinalTrack", "IdealTrack");
fRun->AddTask(trackingQA);
```

Tracking Quality Assurance

Track definitions:

- Fully found
  All MC hits found, All hits of candidate from one track
- Partly found
  $> 70\%$ of MC hits found, All hits of candidate from one track
- Spurious found
  $> 70\%$ of candidate hits from one MC track
- Ghost
  $< 70\%$ of candidate hits from one MC track
- Clone
  Number of MC tracks found more than once

SttCellTrackFinder Efficiencies

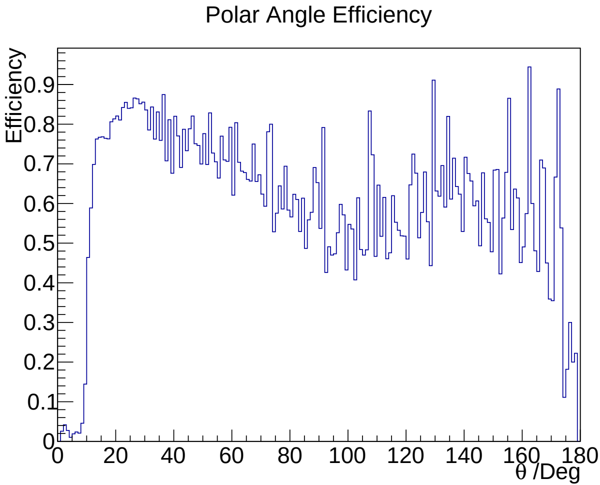
Reconstructible: 3 hits from any detector

	$\Lambda\bar{\Lambda}$ @ 1.64 GeV/c	$\Lambda\bar{\Lambda}$ @ 4.0 GeV/c	$\Omega\bar{\Omega}$ @ 12.0 GeV/c
MC tracks	50381	41158	72561
Reconstructible	47111	34377	69786
Fully found	637	514	647
Partly found	30995	12353	35617
Spurious	1200	592	4220
Ghosts	2909	2649	9334
Clones	27024	31291	37758
$\sum$ found	32832	13459	40484
$\sum$ found %	**69.7**	**39.2**	**58.0**

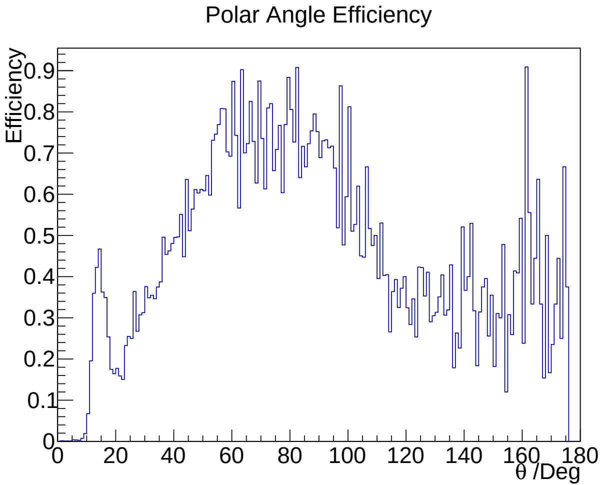
+ Low number of spurious tracks

− Large number of clones

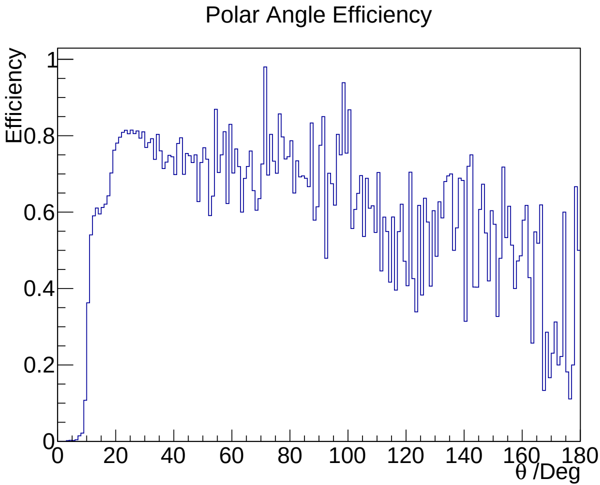
SttCellTrackFinder Efficiencies - $\Lambda\bar{\Lambda}$ @ 1.64 GeV/c



SttCellTrackFinder Efficiencies - $\Lambda\bar{\Lambda}$ @ 4.0 GeV/c



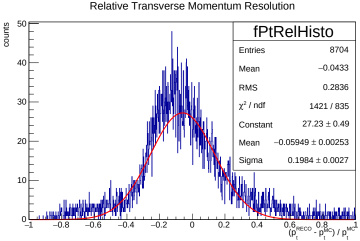
SttCellTrackFinder Efficiencies - $\Omega\overline{\Omega}$, PHSP @ 12.0 GeV/c



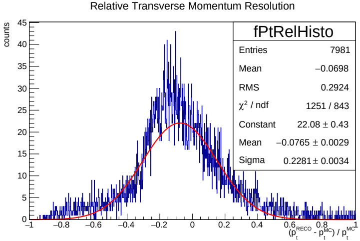
SttCellTrackFinder p_t Resolution - 0.5 GeV π^-

$45 < \theta < 135^\circ$

$(x, y, z) = (0, 0, 0)$ cm



$(x, y, z) = (15, 0, 0)$ cm



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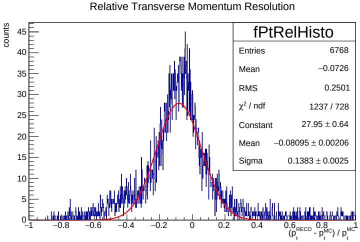

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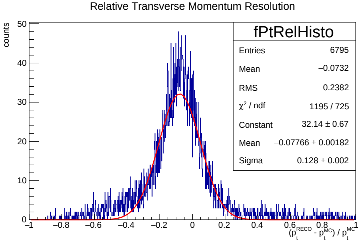

SttCellTrackFinder p_t Resolution - 0.5 GeV p

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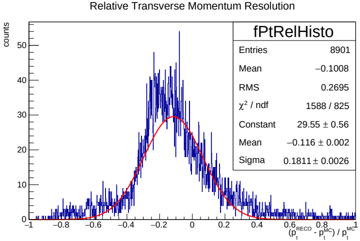

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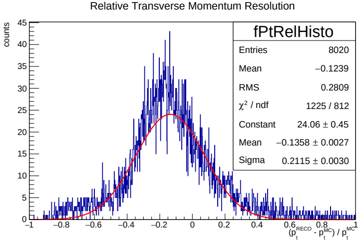

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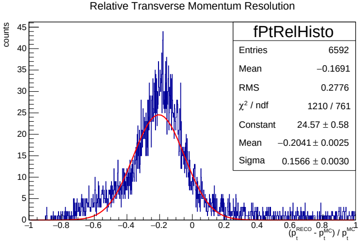

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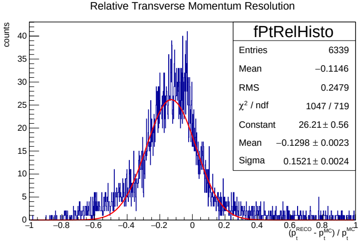
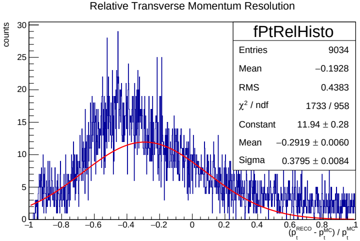


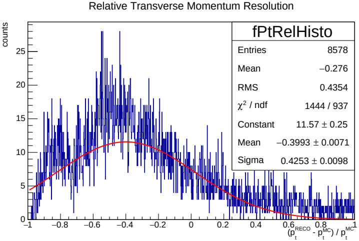
SttCellTrackFinder p_t Resolution - 2 GeV π^-

$\underline{45 < \theta < 135^\circ}$

$(x, y, z) = (0, 0, 0)$ cm



$(x, y, z) = (15, 0, 0)$ cm



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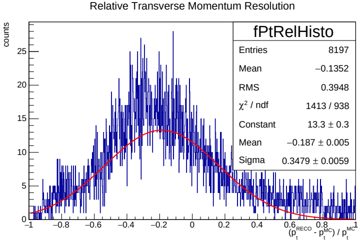
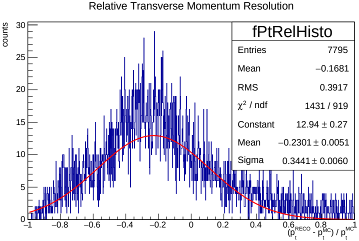
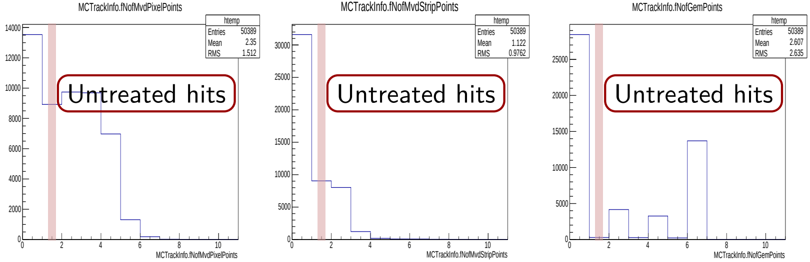


$(x, y, z) = (15, 0, 0)$ cm



SttCellTrackFinder - Untreated hits



- Hits from the MVD/GEM are not currently treated
- Including MVD hits improves accuracy of initial track parameters

Summary and outlook

- Running version of PzFinder on PandaRoot
  - PndTask for running PzFinder, instantiated in usual reconstruction macro
  - Class with algorithmic part
  - PndTask for analysis of output
- Treat the clone tracks
  - Compatibility analysis
  - Track merging
- Extend SttCellTrackFinder clusterization to MVD/GEM hits
  - Improve transversal momentum resolution
  - Improve start track parameters
  - Additional information for $z - \phi$ fit.

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Thank you for your attention!

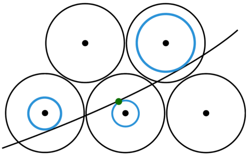
Backup

The $\overline{\text{P}}$ANDA Straw Tube Tracker

STT specifications	
Total straws	4636
Axial layers	15-19
Stereo layers	8
Stereo angle	$\pm$ 2.9 deg

Isochrone radius

Radial distance from track to wire



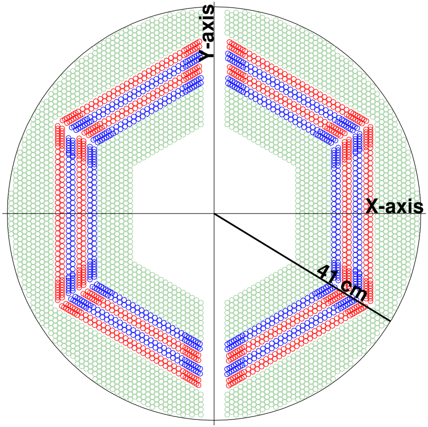


Figure: Cross sectional view of STT
Green - parallel straw
Red, blue - skewed straw

Method 1: Hough transform

Find geometric shapes in images.

- Helix trajectory $\rightarrow$ straight line in $z - \phi$ space
- Line parameters in xy-plane, slope k and intercept m
  - $y(x) = kx + m$

Problem: The intercept parameter m unbound.

Hesse normal form

$$r = x\cos\theta + y\sin\theta$$

$$y = \left(-\frac{\cos\theta}{\sin\theta}\right)x + \left(\frac{r}{\sin\theta}\right)$$

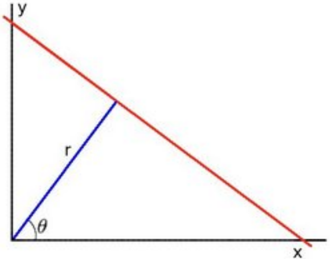
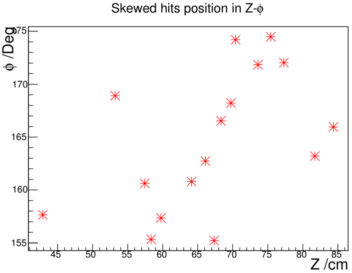


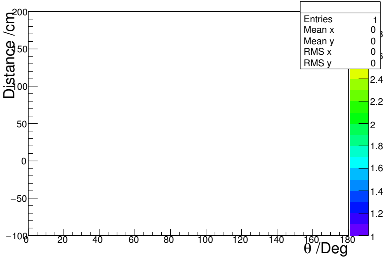
Figure: Blue line perpendicular to red line and crosses the origin

Method 1: Hough transform

The method:

1. Isochrone centers in $z - \phi$ space

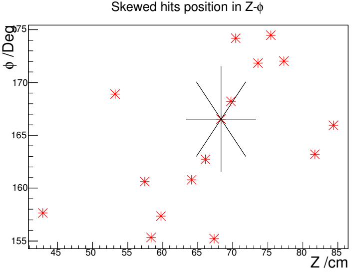


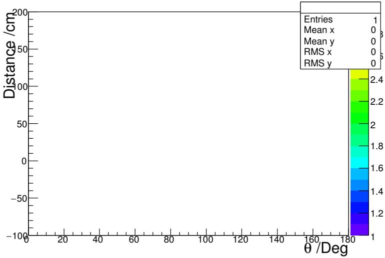


Method 1: Hough transform

The method:

1. Isochrone centers in $z - \phi$ space
2. Generate set of all lines





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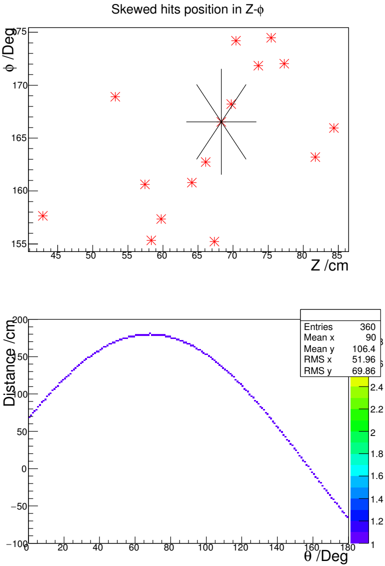
The method:

1. Isochrone centers in $z - \phi$ space
2. Generate set of all lines
3. Parameters $\rightarrow$ accumulator space



Method 1: Hough transform

The method:

1. Isochrone centers in $z - \phi$ space
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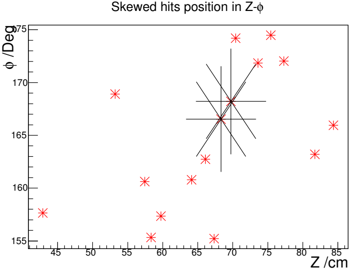
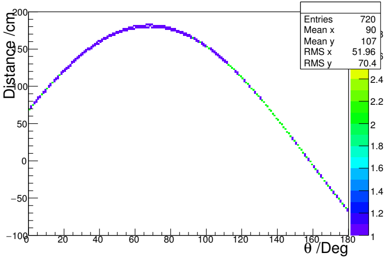
3. Parameters $\rightarrow$ accumulator space
4. Repeat for all points





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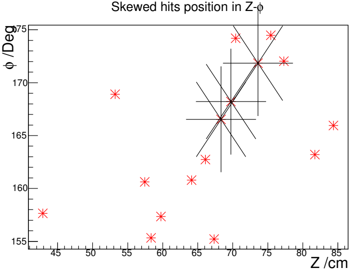

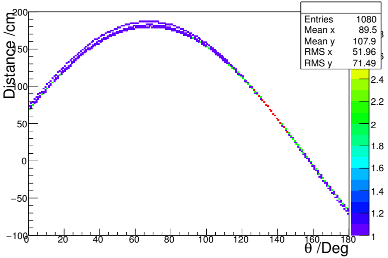

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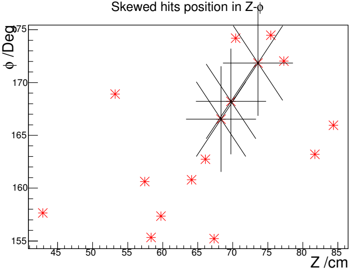
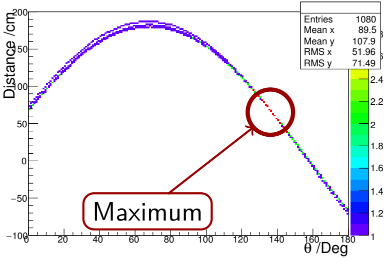
4. Repeat for all points
5. Voting procedure $\rightarrow$ true line

True line found in maximum!





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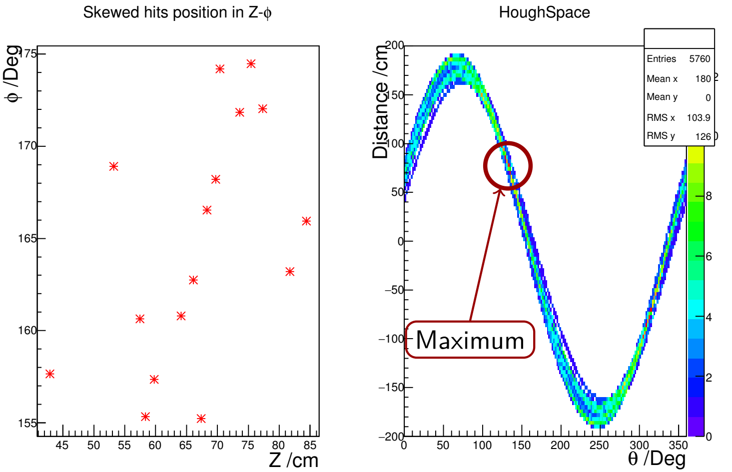


Figure: 360 lines generated for each data point in steps of 1° in θ

Method 1: Extracting helix angle

The method:

1. Calculate point of closest approach (POCA) from hits to true line
2. Accept hit with smallest POCA
3. Straight line fit with selected (z, ϕ) coordinates

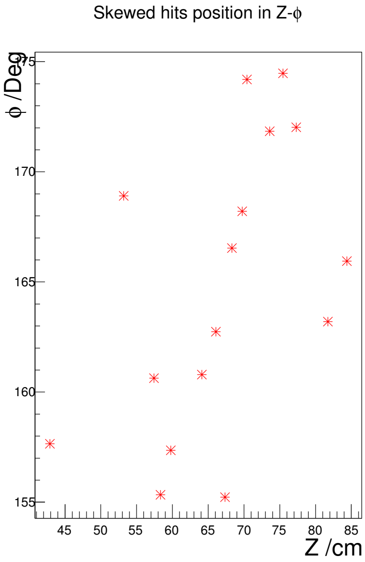
Finish

The slope of the fitted line yields the helix angle. z_0 and p_z can now be extracted!

- z-position assigned to all skewed hits
- Extrapolate helix to first and last parallel hit $\rightarrow$ new FairTrackParP

Method 2: Combinatorics

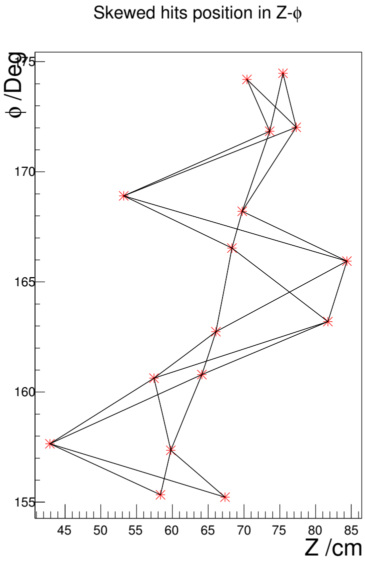
The method:



Method 2: Combinatorics

The method:

1. Calculate all lines between (z, ϕ) points in neighboring skewed straws



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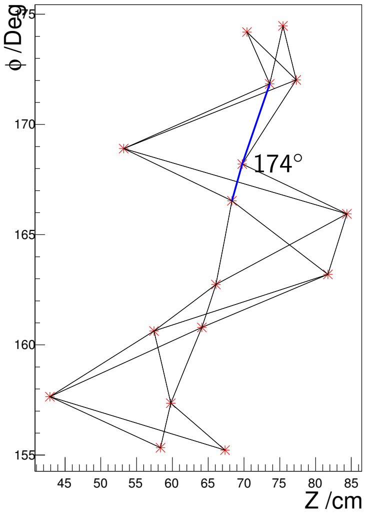
Skewed hits position in Z-ϕ



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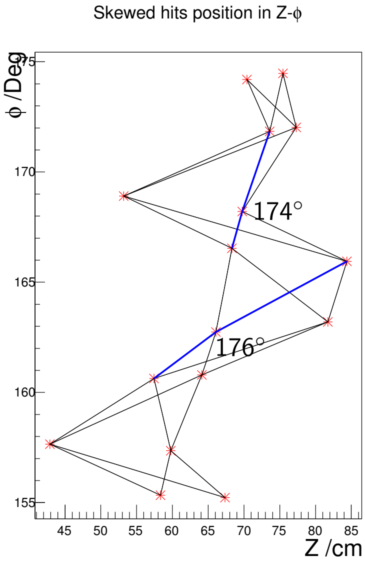

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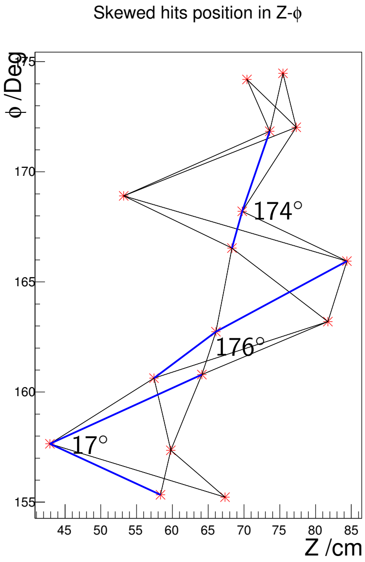

Method 2: Combinatorics

The method:

1. Calculate all lines between (z, ϕ) points in neighboring skewed straws
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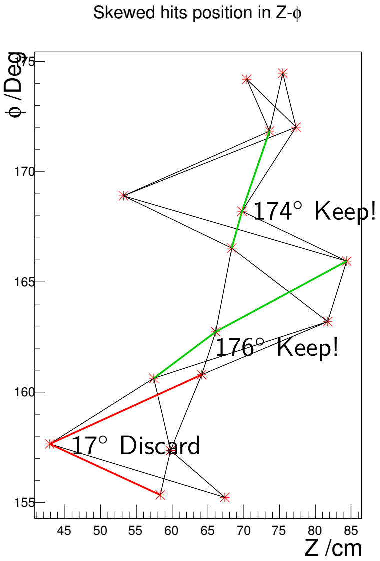
3. Ignore paths where $\theta < 160^\circ$ $\rightarrow$ reduces number of combinations



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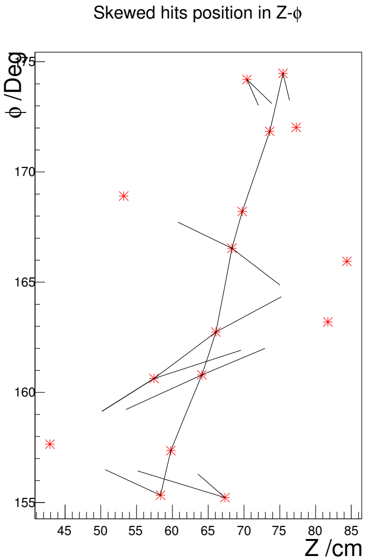

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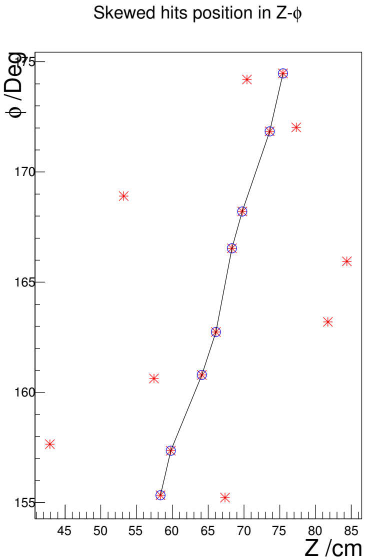
The method:

1. Calculate all lines between (z, ϕ) points in neighboring skewed straws
2. Calculate angle between all possible neighboring lines
3. Ignore paths where $\theta < 160^\circ$ $\rightarrow$ reduces number of combinations
4. Choose path with $\min(\sum \theta_i - 180^\circ)$

Hits in final path chosen as true hits



Hyperon channels in $\overline{\text{P}}$ANDA

Why antihyperon-hyperon production?

- Hyperons produced at scales where QCD is poorly understood
- $\mathcal{CP}$ violation - needed to describe matter in the universe
- Never-before measured hyperon states
- Measure properties *e.g.* spin of hyperons

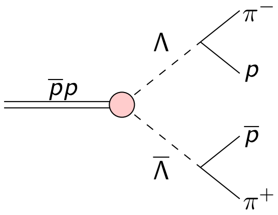


Figure: $\Lambda\bar{\Lambda}$ production channel, scarce data above $\sqrt{s} = 4$ GeV

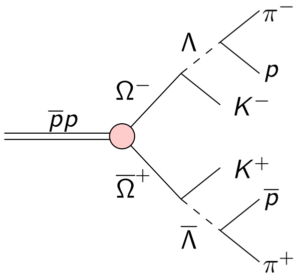


Figure: $\bar{\Omega}^+\Omega^-$ production channel, never measured

Hyperon production $\bar{p}p \to \overline{Y}Y$

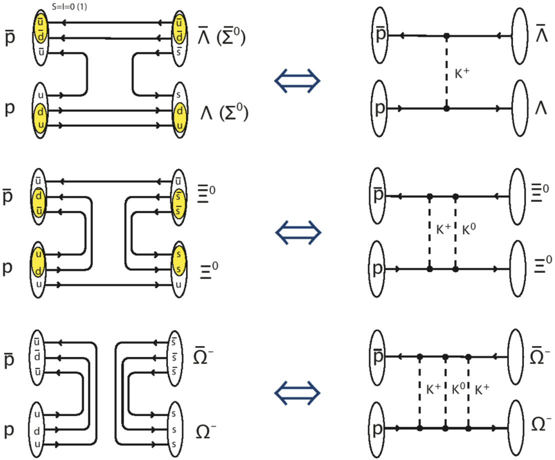


Figure: $\bar{p}p \to \overline{Y}Y$ in quark-gluon picture (left) and in Hadron picture (right).

Hyperons: Spin observables in $\overline{p}p \to \overline{Y}Y$

Spin observables can be used to test theoretical model. Angular distribution related to

$$I \propto \sum_{\mu,\nu=0}^{3} \sum_{k,l=0}^{3} \overline{\alpha}\alpha\chi_{kl\mu\nu} P_k^B P_l^T \overline{k}_\mu k_\nu$$

With unpolarised beam and unpolarised target, differential cross section χ_{0000}, polarisation $\chi_{00\mu 0} = P_{\overline{i}}$, $\chi_{000\nu} = P_i$ and the spin correlations $\chi_{00\mu\nu} = C_{ij}$ are accessible.

Polarisation

- 3 polarisation parameters for spin-$\frac{1}{2}$ hyperons: P_x, P_y, P_z
- $P_x = P_z = 0$ due to strong production
- $P_y = P_{\overline{y}}$ due to rotational invariance

Spin correlation

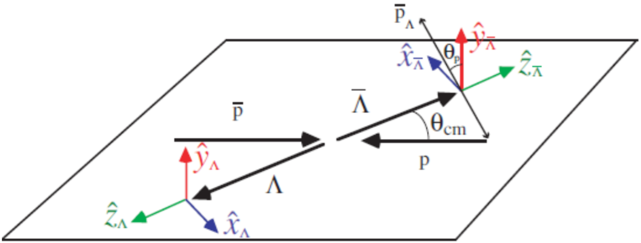
- 9 spin correlation parameters for spin-$\frac{1}{2}$ hyperons: $C_{i,j}$
- $C_{xy} = C_{yx} = C_{yz} = C_{zy} = 0$ due to strong production
- $C_{xz} = C_{zx}$ due to rotational invariance

Hyperons: Spin observables in $\overline{p}p \to \overline{Y}Y$

Polarised Particle	None	Beam	Target	Both
None	I_{0000}	A_{i000}	A_{0j00}	A_{ij00}
Scattered	$P_{00\mu 0}$	$D_{i0\mu 0}$	$K_{0j\mu 0}$	$M_{ij\mu 0}$
Recoil	$P_{000\nu}$	$K_{i00\nu}$	$D_{0j0\nu}$	$N_{ij0\nu}$
Both	$C_{00\mu\nu}$	$C_{i0\mu\nu}$	$C_{0j\mu\nu}$	$C_{C_{ij\mu\nu}}$

- In $\overline{p}p \to \overline{Y}Y$ there are 256 spin variables in total

Hyperons: Spin observables in $\overline{p}p \rightarrow \overline{Y}Y$



Polarisation

Proton angular distribution:

$$I(\theta_p) = \frac{1}{4\pi}(1 + \alpha P_Y \cos\theta_p)$$

$\overline{\alpha}, \alpha$ - decay asymmetry parameter

Spin correlation

Nucleon angular distribution:

$$I(\theta_i, \theta_j) = \frac{1}{16\pi^2}(1+$$

$$\overline{\alpha}\alpha \sum_{i,j} C_{ij} \cos\theta_i \cos\theta_j)$$

Accessible hyperons at $\overline{\text{P}}$ANDA

$$\bar{p}p \rightarrow \bar{\Lambda}\Lambda,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Sigma}^0\Sigma^0,\ \bar{\Sigma}^-\Sigma^+,\ \bar{\Xi}^0\Xi^0,\ \bar{\Xi}^+\Xi^-,\ \bar{\Omega}^+\Omega^-,\ \bar{\Lambda}_c^-\Lambda_c^+$$

$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$p\pi^-$	$p\pi^0$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^0$	$\Lambda\pi$	ΛK	$\Lambda\pi$
64%	52%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	$\approx$ 100%	68%	$\approx$ 1%