

Implementation of a trackfinding-algorithm for the forward tracking system of the PANDA-detector

Felix Kibellus
Forschungszentrum Jülich
IKP - 1

September 24, 2016

Abstract

The forward tracking system (FTS) is a straw-tube based detector in the forward-part of the PANDA-detector. It is specializing in reconstruction of particle trajectories. The FTS consists of six stations. Each station consists of four doublelayer straw-tubes. The second doublelayer is skewed 5 to the right and the third doublelayer is skewed 5 to the left. The first and the fourth doublelayer are not skewed. The stations are numbered with FTS1-FTS6. Between FTS2 and FTS5 is a magnetic field located so charged particles will be distracted to the left or to the right. If a particle fly through the FTS there will be FTS-hits at the position of the taken straw-tubes created. It is necessary to reconstruct the trajectories of the particles which are crossing the FTS. In this thesis an algorithm has been developed which gets FTS-hits and creates PndTracks for the trajectory in the FTS.

1 Introduction

The implemented algorithm has six steps:

1. Create track-candidates
2. Approximate lines
3. Combine lines inside one FTS-station
4. Combine lines between FTS-stations
5. Find tracks inside the magnetic field
6. Add hits which were not found in the steps before

This steps will be explained in the following chapters.

2 Create track-candidates

The first step of the algorithm is a cellular automaton. The algorithm starts with initializing each FTS-hit with a unique state. Therefore the tube-ID is used. After that, the cellular automaton sets the state for each hit to the minimum of the own state and the state of the neighbours. This step will be repeated until no state is changing. Finally the algorithm can group all hits with the same state to one track candidate. Figure 1 shows the steps of the cellular automaton. The first part of the figure shows the initialization of all hits with the unique tube-ID. In the second part of the figure all states were updated. Now we got two different track-candidates.

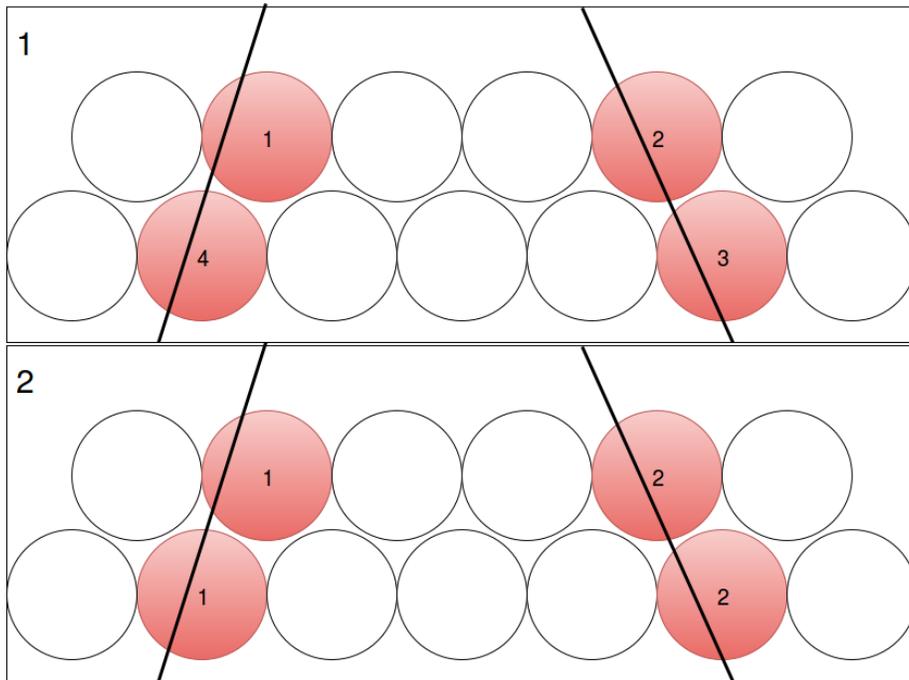


Figure 1: Changing of the states by the cellular automaton

A track-candidate with two hits is the normal case. This case will be created the most often because the likelihood for exact two hits per double layer is the highest. While creating the track-candidates it can be created different special cases. Figure 2 shows the different special cases. In case one a particle hits only the boarder of the FTS. In the case only one hit will be added to the track candidate. It is possible that a particle fly exactly between to straw-tubes. In this case also one hit will be added to the track-candidate. In the figure you will find this special case as the track with the id two. The special case three will be created if a particle fly in a pointed angle through the FTS. In this case

more than two hits will be added to the track-candidate. Special case four will be created if two particles are crossing each other inside one doublelayer straw-tubes. The special cases needs to be processed differently in the following steps of the algorithm.

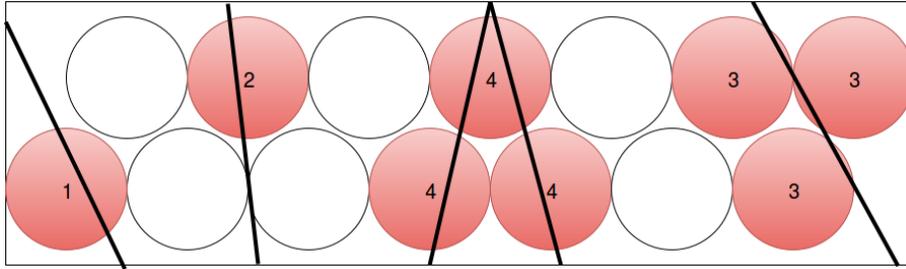


Figure 2: Special cases which can be created by the cellular automaton

3 Approximate lines

In the next step the algorithm approximate lines for each neighboring straw-tubes of one track-candidate. With the help of the isochrones four possible approximations can be created. Figure 3 shows the four possible approximations for the normal case with two hits. One of the approximated lines is the correct one, the other three are wrong. The problem is that the algorithm can not decide which is the correct one with the available information. This will be possible in future steps of the algorithm.

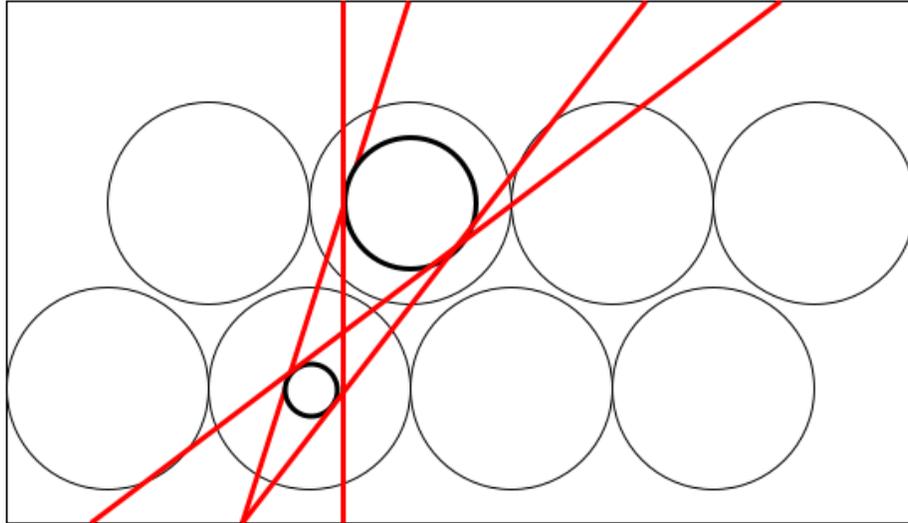


Figure 3: Possible line-approximations for two neighboring straw-tubes with the isochrones

If the track-candidate contains more than two hits there are different cases.

3.1 Track-candidates with one hit

If the track-candidate contains only one hit it is not possible to create a approximation because there are infinity possibilities. This track-candidates needs to be ignored in this step of the algorithm. Because of that the algorithm needs to integrate this hits in a later step.

3.2 Track-Candidates with more than two hits

If the track-candidate contains more than two hits there are two different cases. In the first case the algorithm can find a unique line. In this case the algorithm will choose the unique line and delete the others. For the following steps will only be used the unique line. In the second case the algorithm can not find a unique line. In this case the algorithm gets all possible lines for the following steps.

3.3 Approximate lines for skewed straw-tubes

There is a problem with skewed straw-tubes. Figure 4 shows this problem. In the last steps was only used the 2-dimensional projection of the isochrones. This is a problem for skewed straw-tubes because the position of the projection is depending on the Y-height of the track.

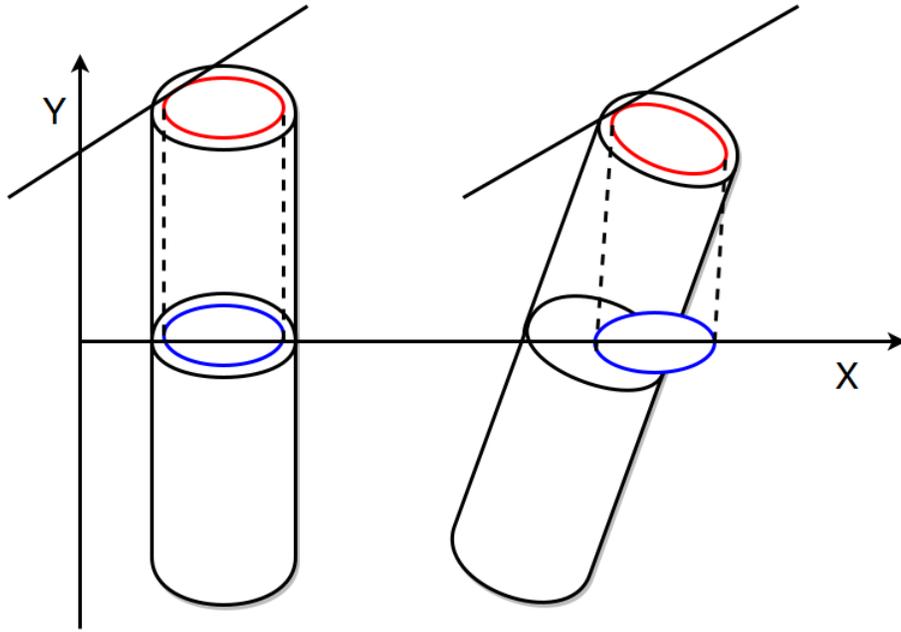


Figure 4: Problems with the projection of the isochrone

The problem can be solved with a coordinate transformation. Figure 5 shows the straw-tube after a coordinate transformation. The coordinate system was rotated by the angle of the straw-tube. This is 5 to the left or the right depending on the layer of the straw-tube. After the transformation the use of the projection is no problem. The position of the projection is no more depending on the Y-position of the track.

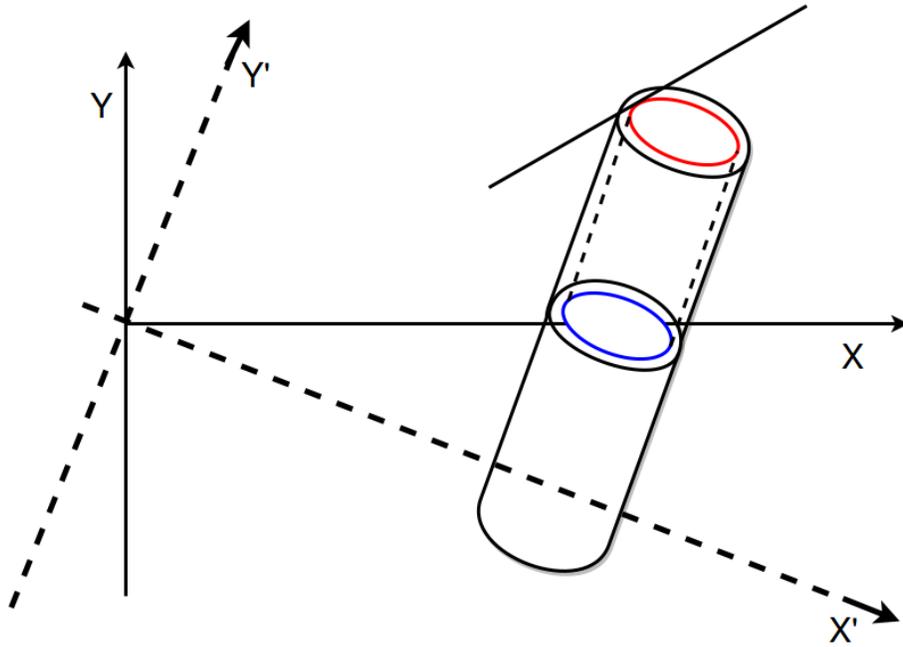


Figure 5: Solving the problem with a coordinate transformation

3.4 correction of the hit-position

The position of the hits is initial equal to the mid of the straw tubes. In the following steps a linear regression will be used to get a better approximation. The result of the linear regression will be better if the points are more accurate. Because of this the hit position will be corrected after the approximation was created. Figure 6 shows the straw tubes with the corrected hit position. The new hit position will be set to the point where the approximation is tangential to the isochrone. The correction is depending on the created approximation. Because of this it is necessary to create a correction for each created approximation.

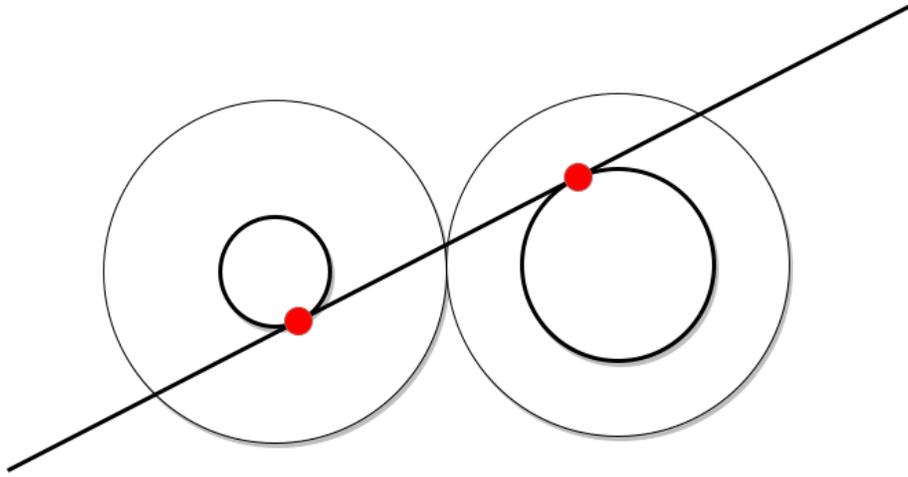


Figure 6: Correction of the hits

4 Combine lines inside one FTS-station

In this step the algorithm combines lines inside one FTS-station. The algorithm starts with combining the 1st and the 4th layer. Therefore it search for similar lines. Lines are similar if the following similar criteria are be present:

similar angle If the angle between the lines is not about 180 the lines will not be assess as similar.

distance between the pearcing points The second criteria is the distance between the pearcing points of the lines through the plane between the 1st and the 4th layer. This points needs to be near to each other.

It is not advantageous to use direct the distance between the lines. It is necessary to define similarity in a short region. If the distance between the lines is short in a uninteresting region but not near to each other in the consider FTS-station the lines should not be assessing as similar. If the algorithm found similar lines it combines than two one line with the help of a linear regression.

Now the algorithm includes the second and the third double layer straw tubes. In the previous steps Therefore it creates planes for each approximation.

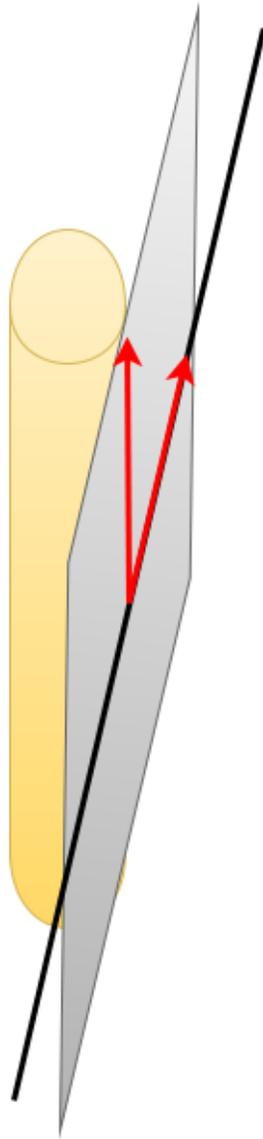


Figure 7: Creation of the planes with the help of the both direction vectors

The creation of the planes is shown in figure 7. The first direction vector is the approximation of the step before. The second direction vector is parallel to the corresponding straw tube.

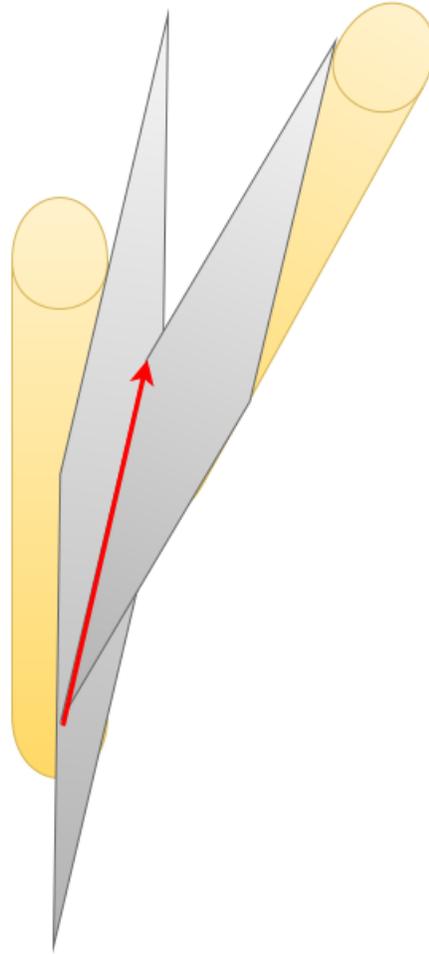


Figure 8: Calculation of the intersection line of two planes from different layer

Now the algorithm calculate the intersection lines of the two planes from different layer. This is shown in figure 8. The created intersection line is a approximation for the correct track. The algorithm combines the following double layer:

1. Merged layer 1 and 4 with layer 2
2. Merged layer 1 and 4 with layer 3
3. Layer 2 with 3

In the created intersection lines the algorithm search again for similar lines with the help of the previous similar criteria. If two part approximations will are similar the algorithm merge them with a linear regression to one track. In

this step a line is created which goes through a full FTS-station. If less than two lines can be match the algorithm will not use them for future steps.

5 Combine lines between FTS-stations

In the next step the algorithm combines lines between the FTS-stations. The algorithm combines FTS1 with FTS2 and FTS5 with FTS6. Therefore the similar criteria are used. If two similar tracks was found they will be merged with the help of a linear regression. So the algorithm create approximations for both FTS-stations. It is possible that a track only crosses one FTS-station. In this case the track will also will be used for future steps although no similar track was found.

Figure 9 shows the tracks before combining the FTS-stations. The yellow arrows shows the lines which represent the part approximations. The red points are the corrected FTS-hits. It falls on that the approximation quality is high in the XZ-projection and low in the YZ-projection. Figure 10 shows the approximations after the combining of the FTS-stations. The yellow arrow includes now both FTS-stations. The correction of the FTS-hits is really better because of the linear regression.

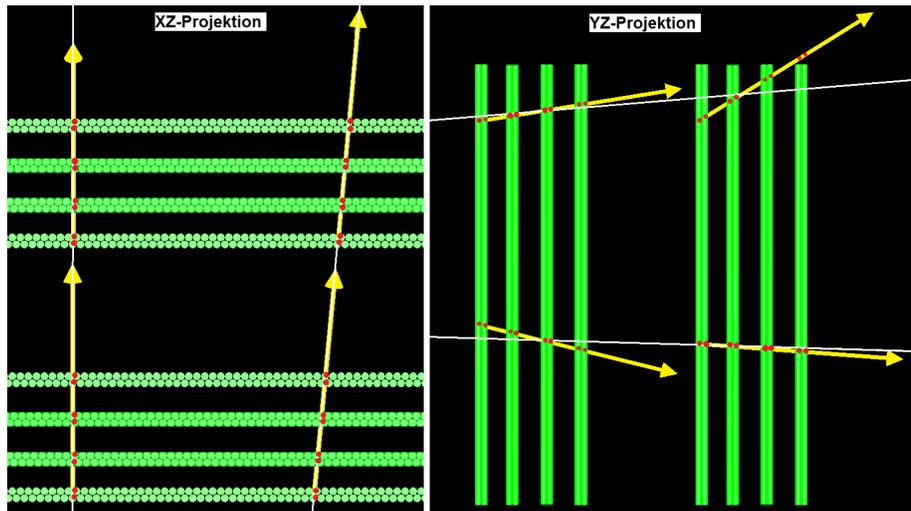


Figure 9: Visualization of the reconstructed tracks before combining FTS-stations

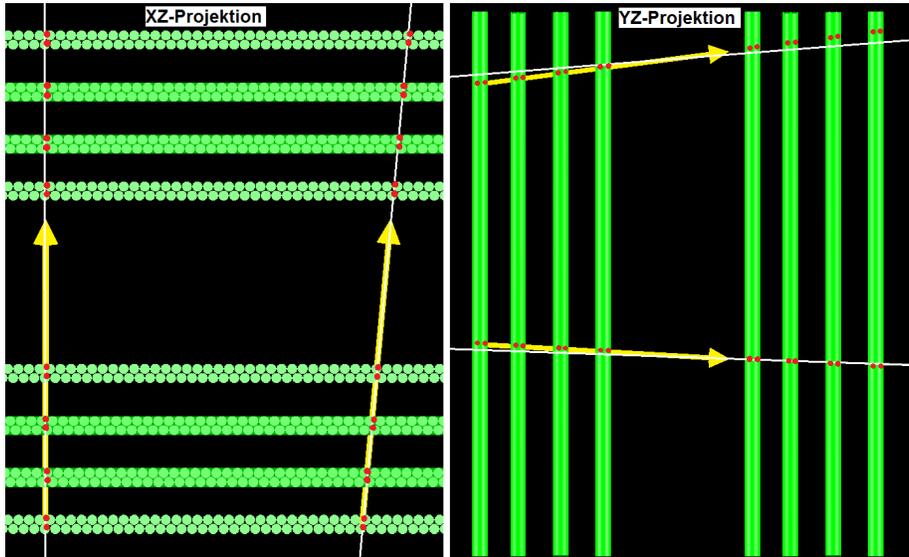


Figure 10: Visualization of the reconstructed tracks before combining FTS-stations

6 Find tracks inside the magnetic field

The previous algorithm is used for FTS1, FTS2, FTS5 and FTS6. Between FTS2 and FTS5 is a magnetic field located. Tracks will be distracted to the left or to the right inside the magnetic field. Consequently the track can not be approximated as a line inside the magnetic field. Inside the magnetic field an alternative algorithm needs to be used. Therefore a way follower is used. The way follower starts with the approximation of FTS1 and FTS2. Then it picks the best fitting part approximation of each double layer straw tubes. Step by step the way follower goes through the magnetic field. Figure 11 shows the the part approximation of the different double layer.

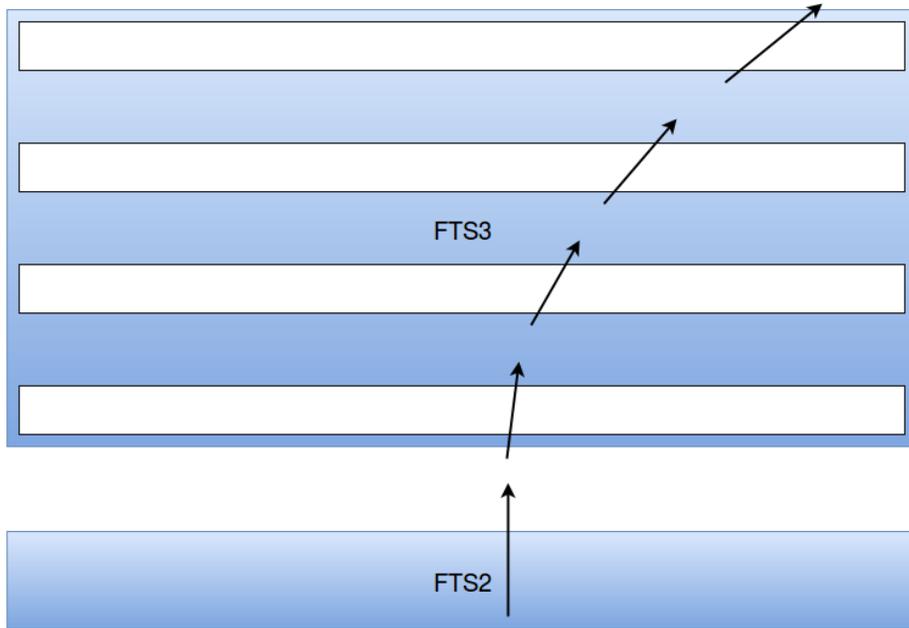


Figure 11: Reconstruction of tracks inside the magnetic field with a way follower

7 Add hits which were not found in the steps before

The last step of the algorithm is adding hits which were not found in the steps before. It is possible that the previous steps can not add all correct hits of the track. Nevertheless a correct track can be reconstructed. Consequently it can be decided whether the hits which were not found be part of the track. In this last step the algorithm calculate the distance of each not found hit to the tracks. If the distance is less than the isochrone radius the hit can be added to the track.

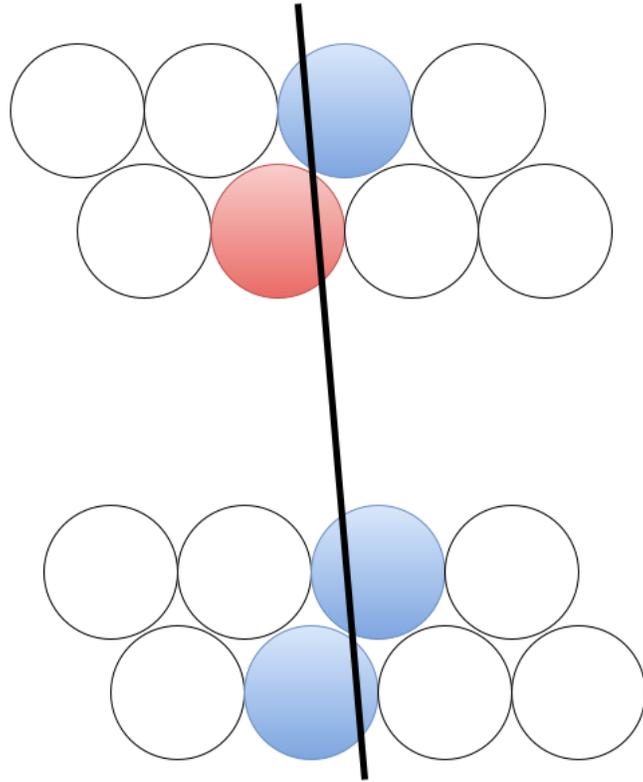


Figure 12: Adding hits afterwards which was not found in the previous steps

Figure 12 shows two double layer of straw tubes. The blue hits were added by the previous steps. The red hit was not added to the track. Due to the distance to the track it is clear that the hit is a part of the track. Consequently the algorithm can add the hits afterwards.