Measuring the detector efficiencies of a 8-detector Muon Tomography Station

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Overview

- Background
- Method
- Results

Background

Importance and Goals

- Need to know detector efficiency to understand reliability of the muon tomography station data

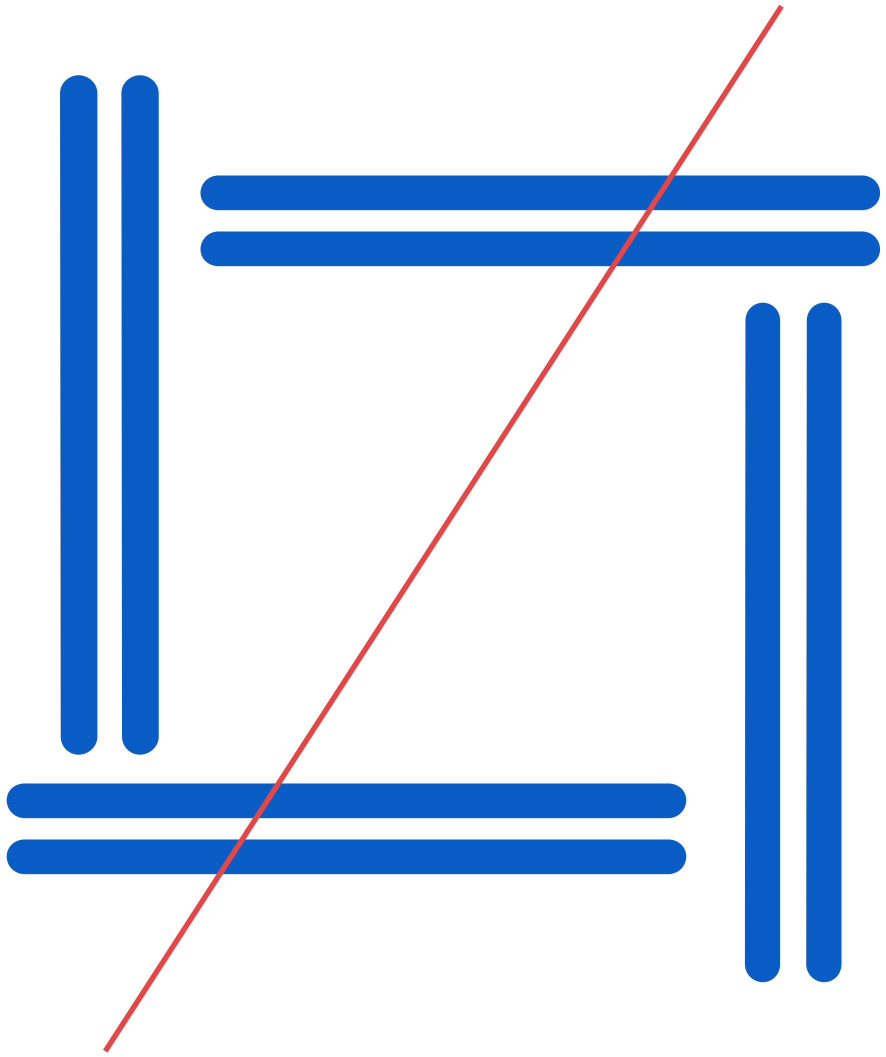
- Goals

  1. Calculate a percent efficiency for each detector

  2. Use a 2D histogram to map out the efficiency of each detector

The GEM detector

- GEM = Gas Electron Multiplier
- Gives the xy coordinates of the hit location when a muon passes through it
- Florida Tech Muon Tomography Station (MTS) uses 8 detectors



Muon tomography station
GEM detector geometry (side view)
with example muon track

What is the efficiency?

- The efficiency is the number of "successful" hits with that detector divided by its total number of hits

- A detector's efficiency is affected by:

  1. Detector resolution

  2. Detector alignment

  3. Track selection algorithm

Track Selection

- Iterates through all detectors
- Finds events with single clusters and puts them together
- Single clusters - one x hit and one y hit was found
- Looks for tracks where two pairs of detectors are hit

Method

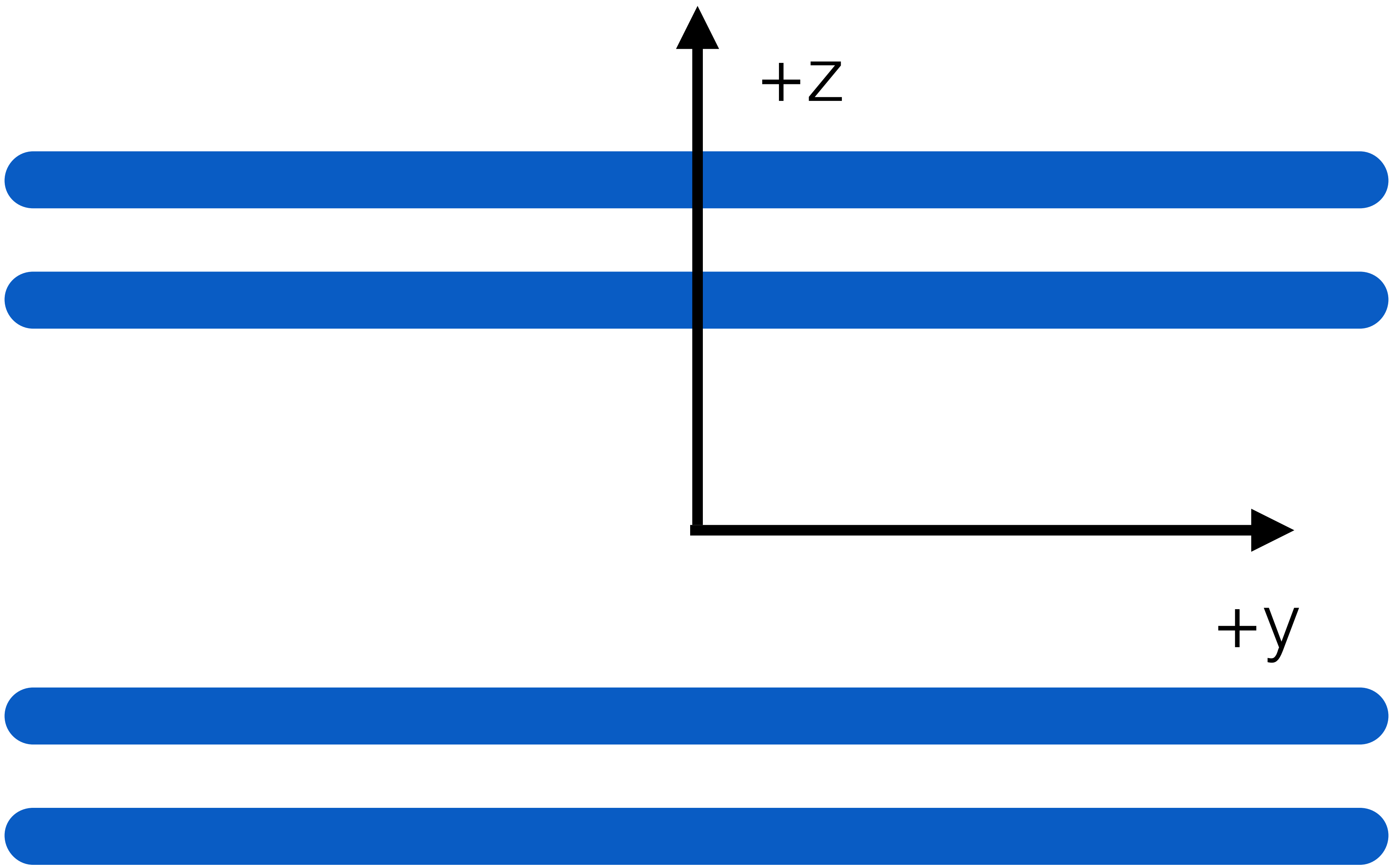
Algorithm

1. Obtain data for an empty station

2. For every detector, count the number of events where it had a "successful hit"

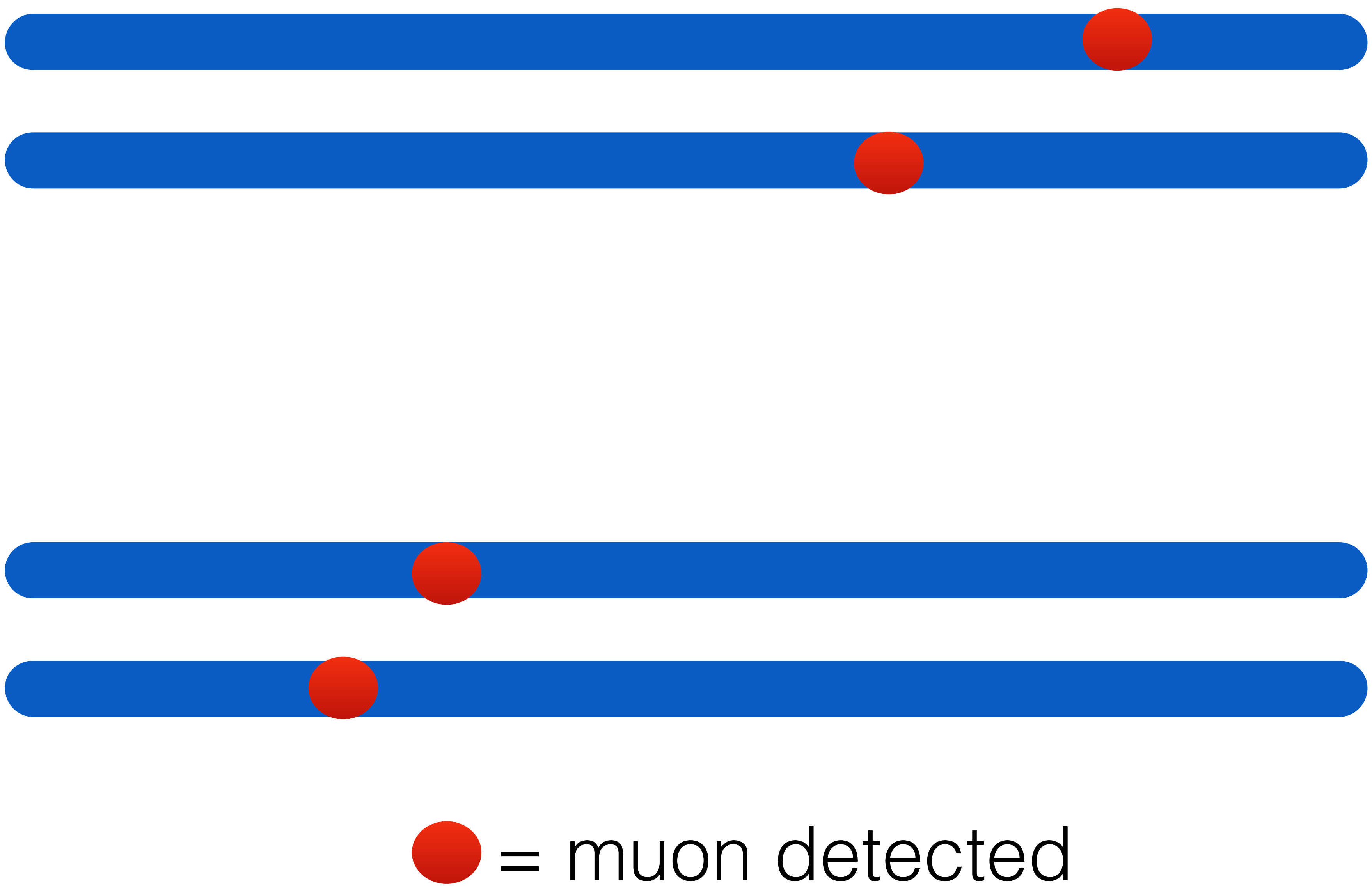
3. Divide the number of that detector's successful hits by the total number of hits to get its efficiency

Determining "success"

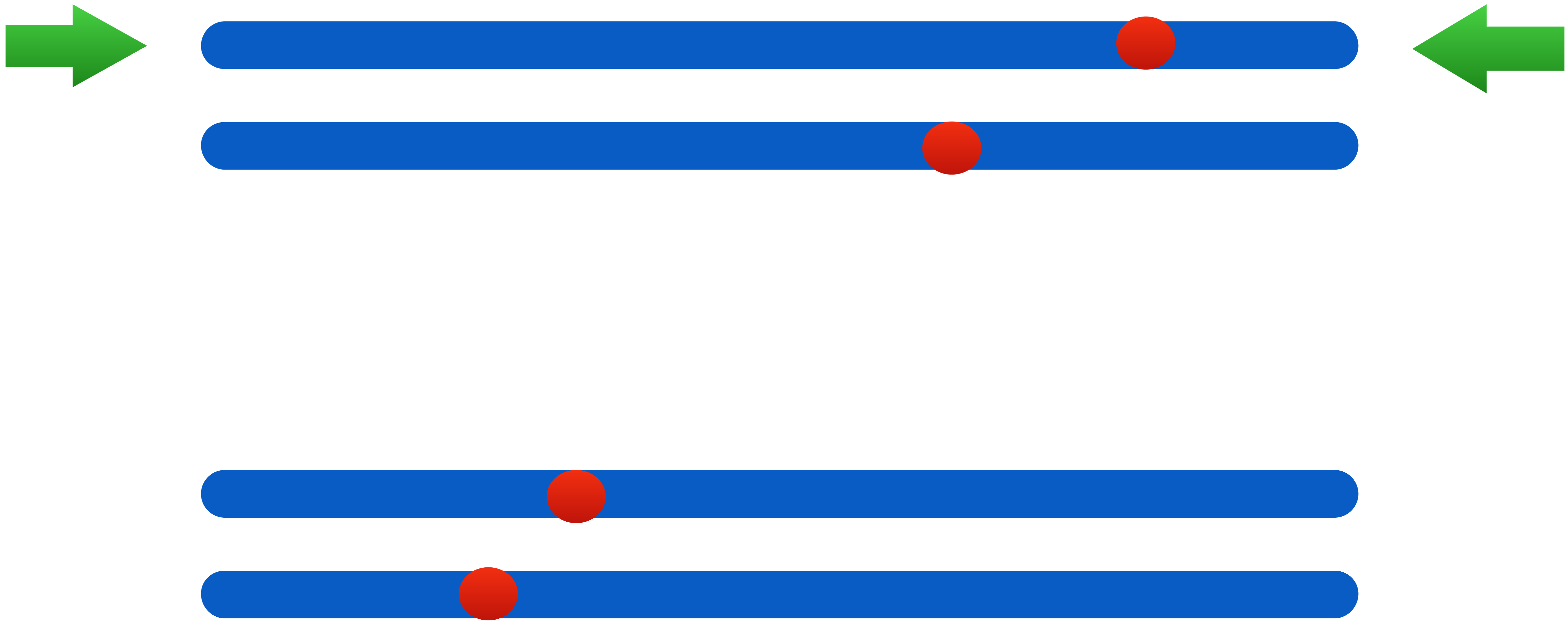


Starting with an empty 4-detector station

Determining "success"

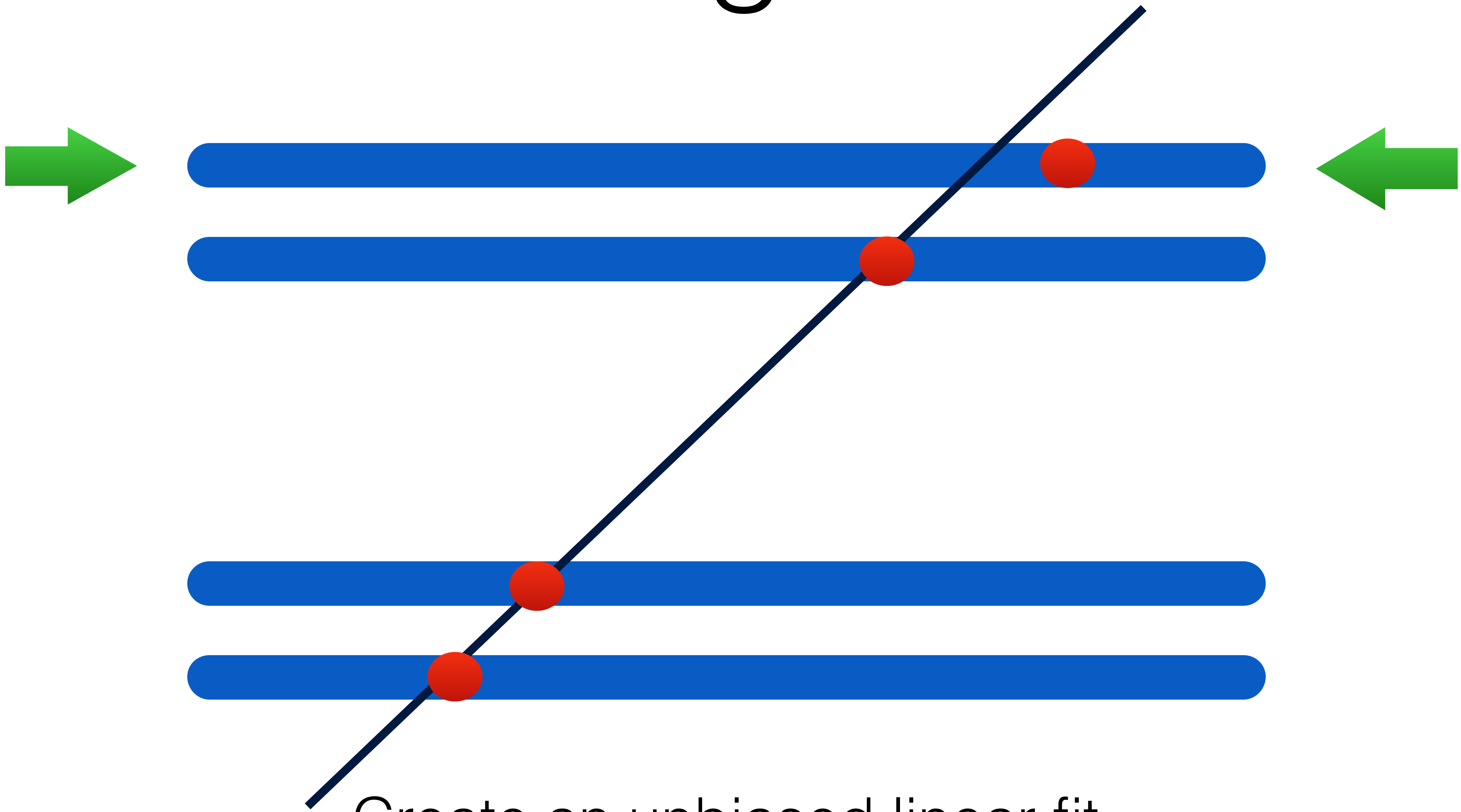


Determining "success"



Let's analyze the top detector

Determining "success"



Create an unbiased linear fit
(exclude detector under investigation)

Linear fit algorithm

$$x(z) = a_x + b_x z$$

$$a_x = \frac{\Sigma z * \Sigma xz - \Sigma z^2 * \Sigma x}{(\Sigma z)^2 - n * \Sigma z^2}$$

$$b_x = \frac{\Sigma z * \Sigma x - n * \Sigma xz}{(\Sigma z)^2 - n * \Sigma z^2}$$

Fit in x direction

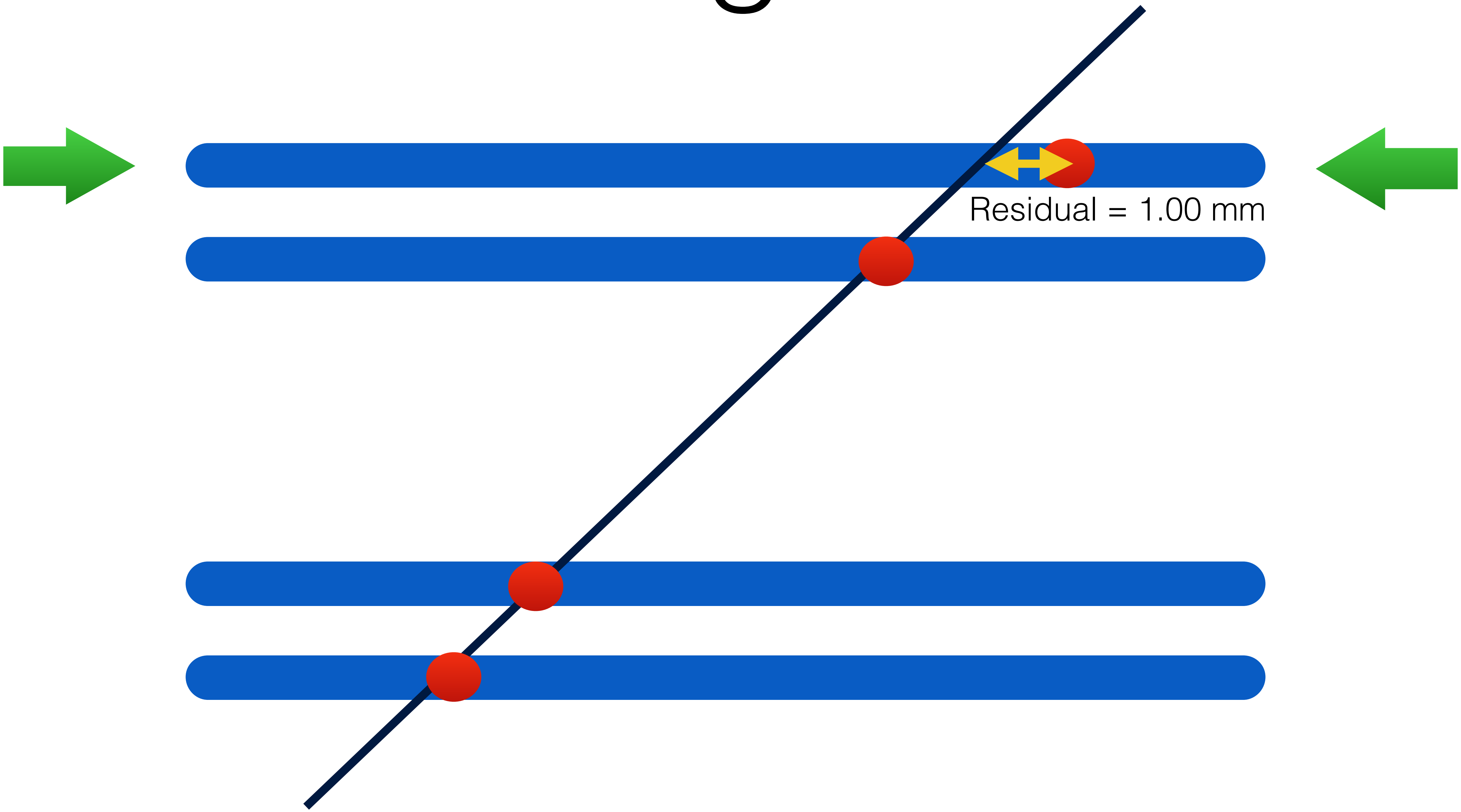
$$y(z) = a_y + b_y z$$

$$a_y = \frac{\Sigma z * \Sigma yz - \Sigma z^2 * \Sigma y}{(\Sigma z)^2 - n * \Sigma z^2}$$

$$b_y = \frac{\Sigma z * \Sigma y - n * \Sigma yz}{(\Sigma z)^2 - n * \Sigma z^2}$$

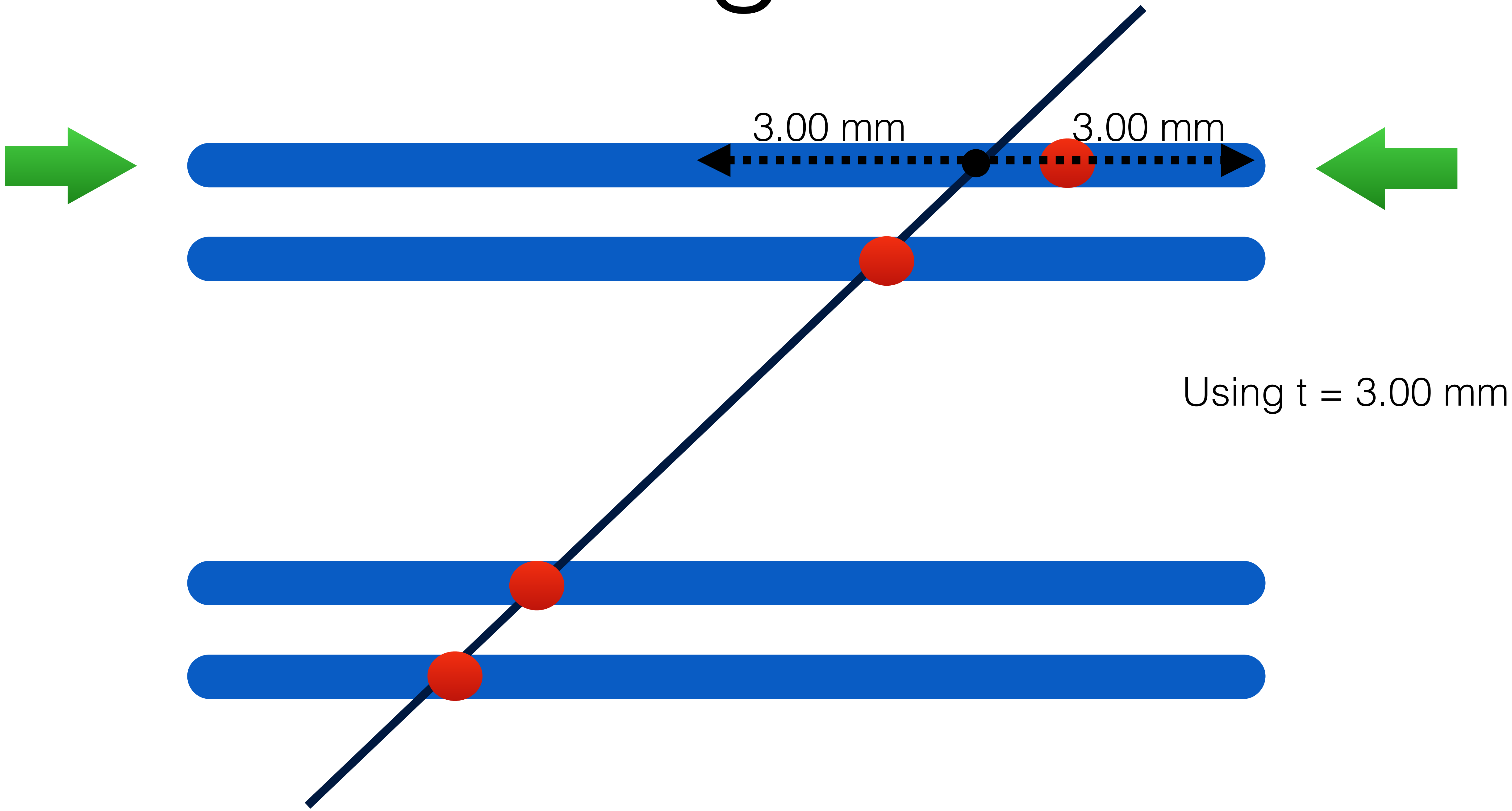
Fit in y direction

Determining "success"



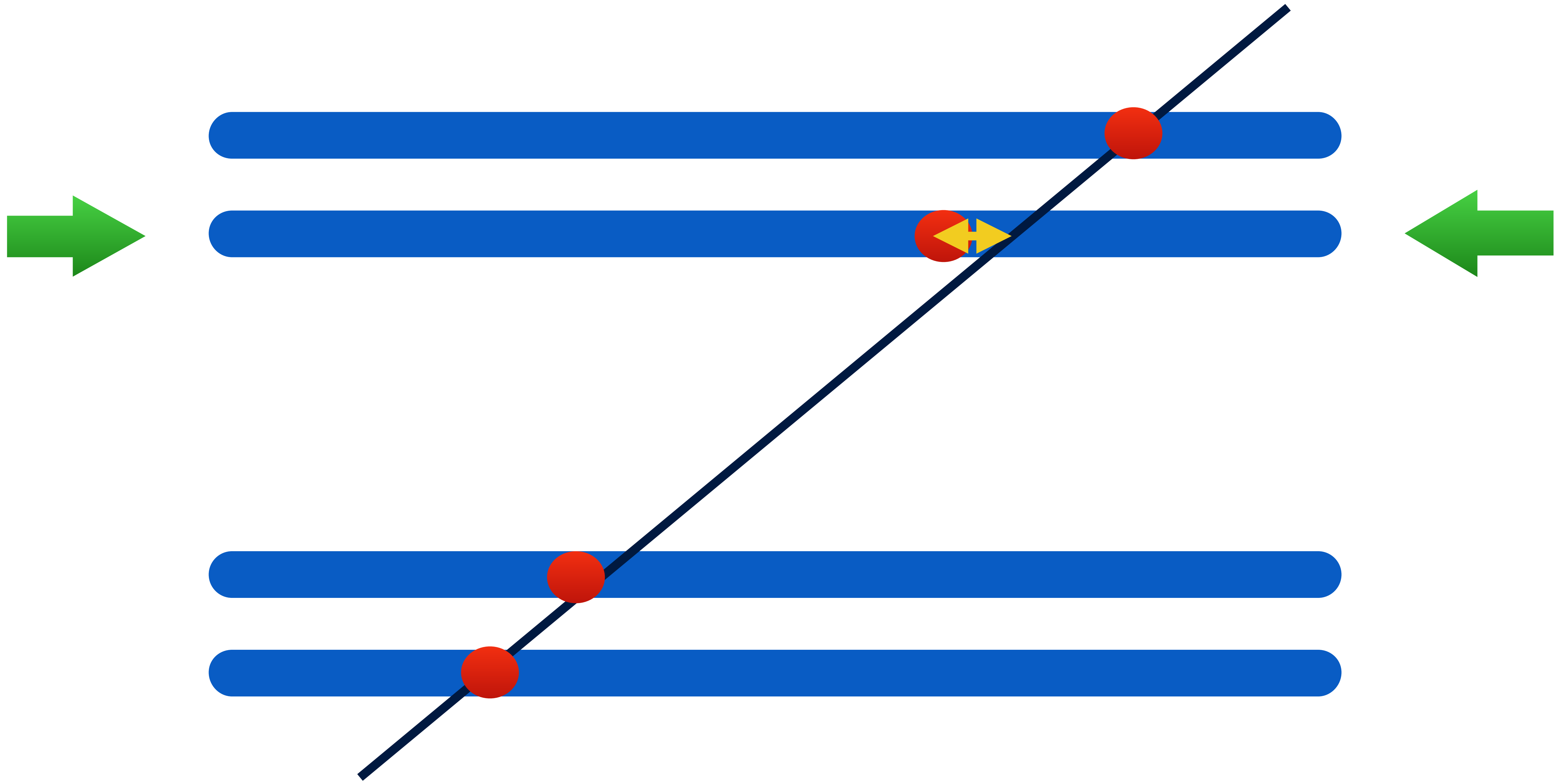
Measure distance between the linear fit and the actual hit

Determining "success"



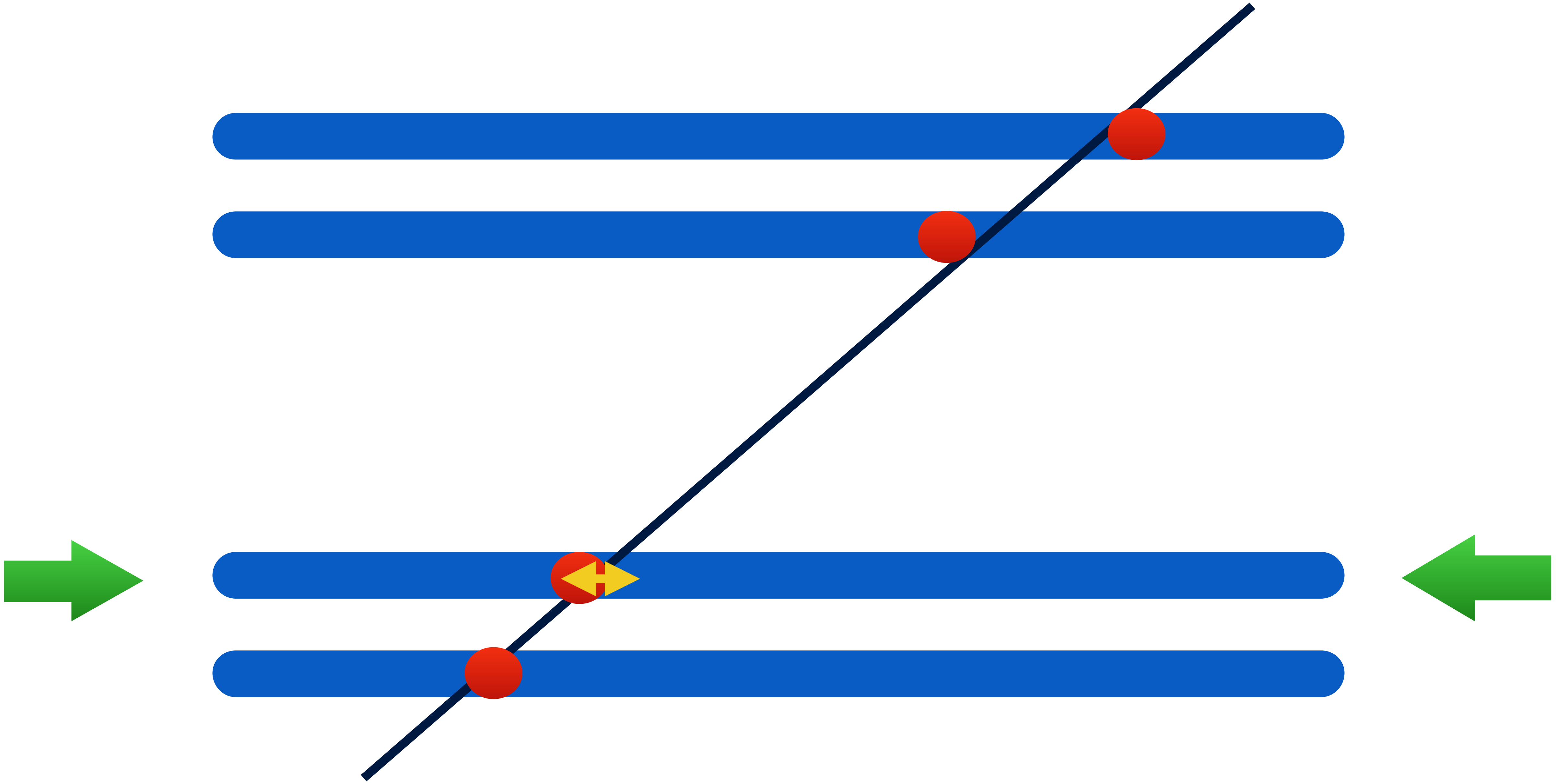
Compare the residual *r* to a given threshold value *t*.
If $r < t$ (as in this case), then the hit is successful.

Continue to next detector



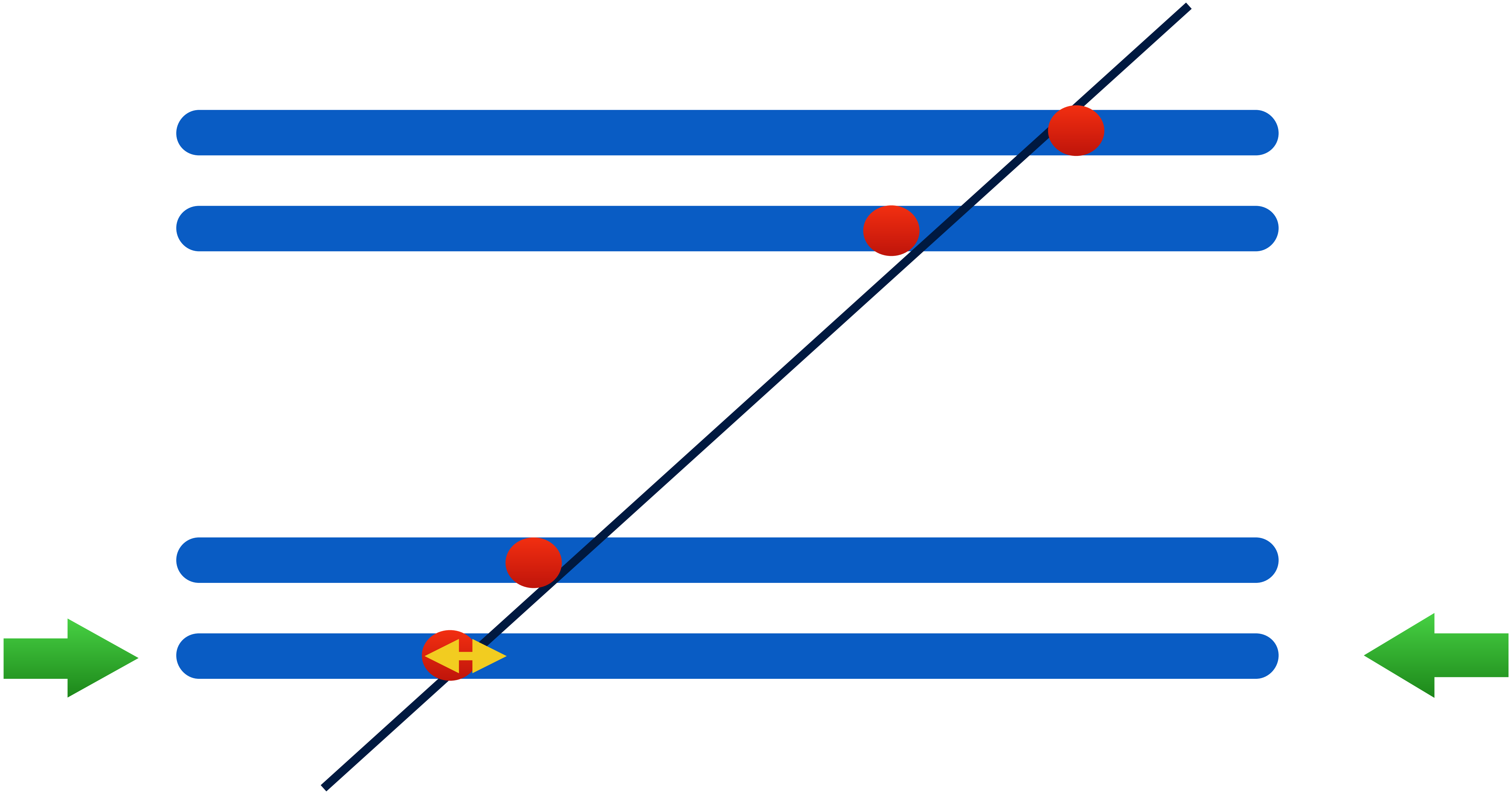
Repeat for all the other detectors

Continue to next detector



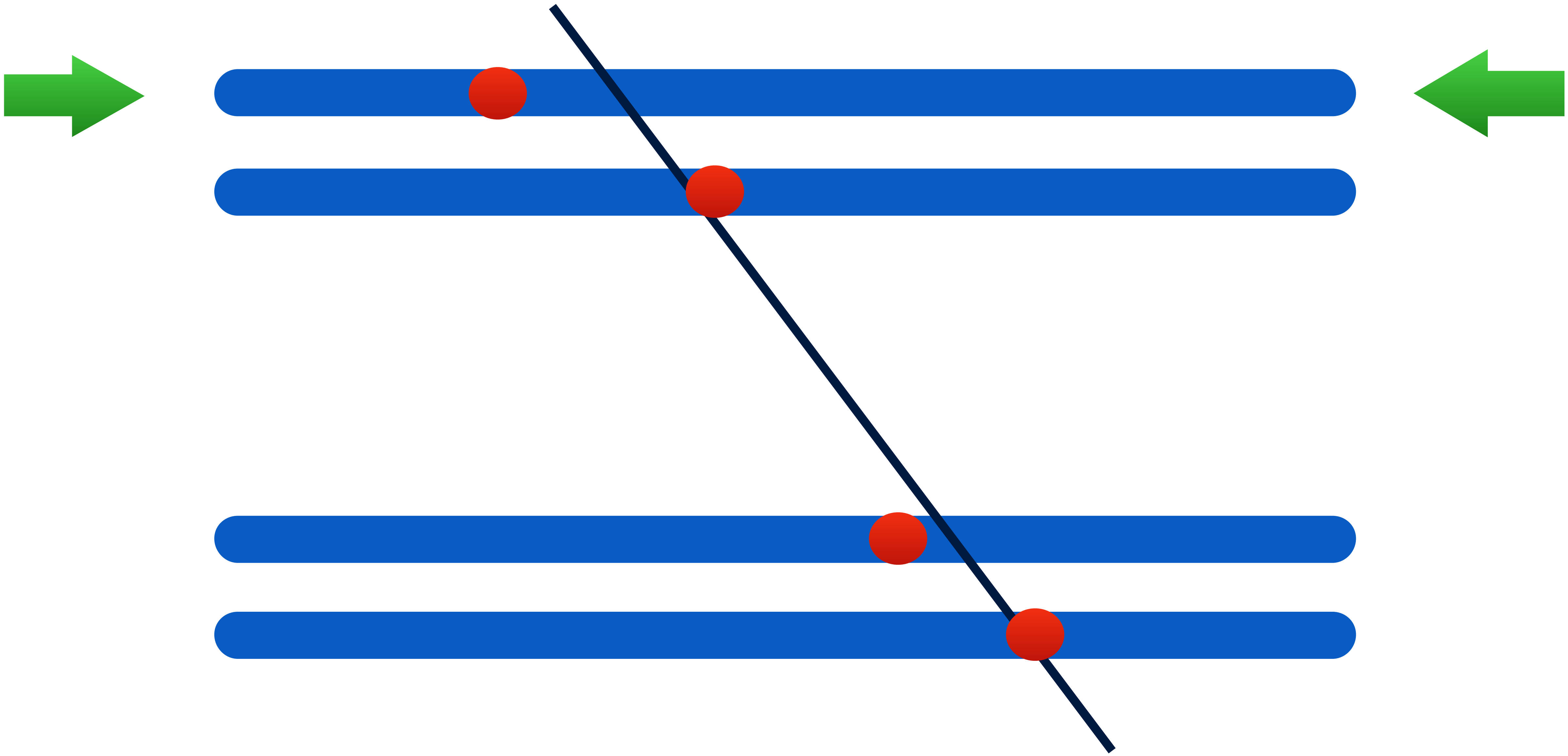
Repeat for all the other detectors

Continue to next detector



Repeat for all the other detectors

Continue to next event



Repeat for all the other events

Adjusting for side detectors

New fit for x

$$x(y) = a'_x + b'_x y$$

$$a'_x = a_x - a_y \frac{b_x}{b_y}$$

$$b'_x = \frac{b_x}{b_y}$$

New fit for z

$$z(y) = a'_z + b'_z y$$

$$a'_z = -\frac{a_y}{b_y}$$

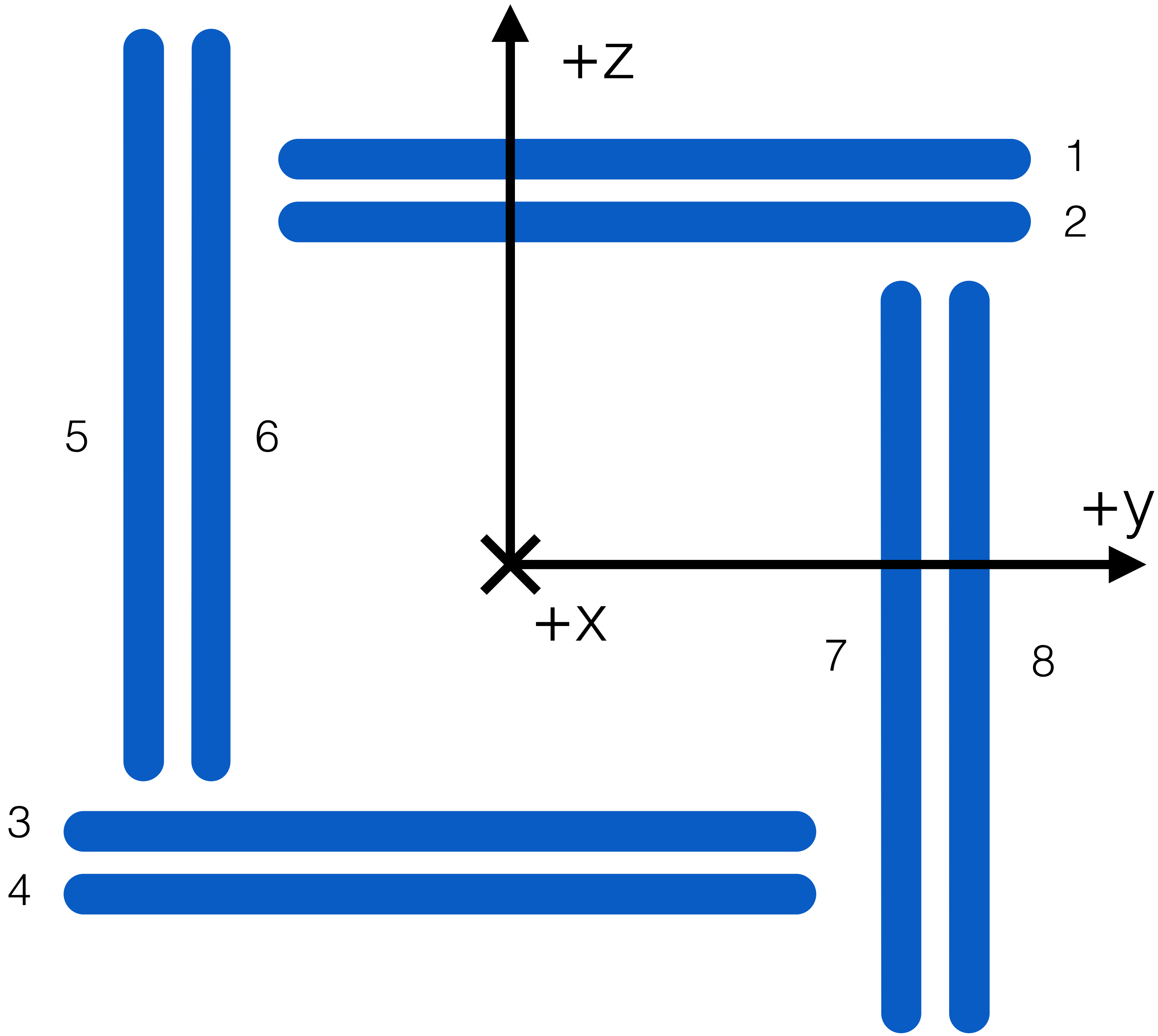
$$b'_z = \frac{1}{b_y}$$

Results

Data/Tools Used

- 8-detector empty setup
- 100,000 events with hits on four detectors
- Threshold value t = 0.75 mm
  - 0.75 mm ~= 5 times the detector resolution

Station geometry



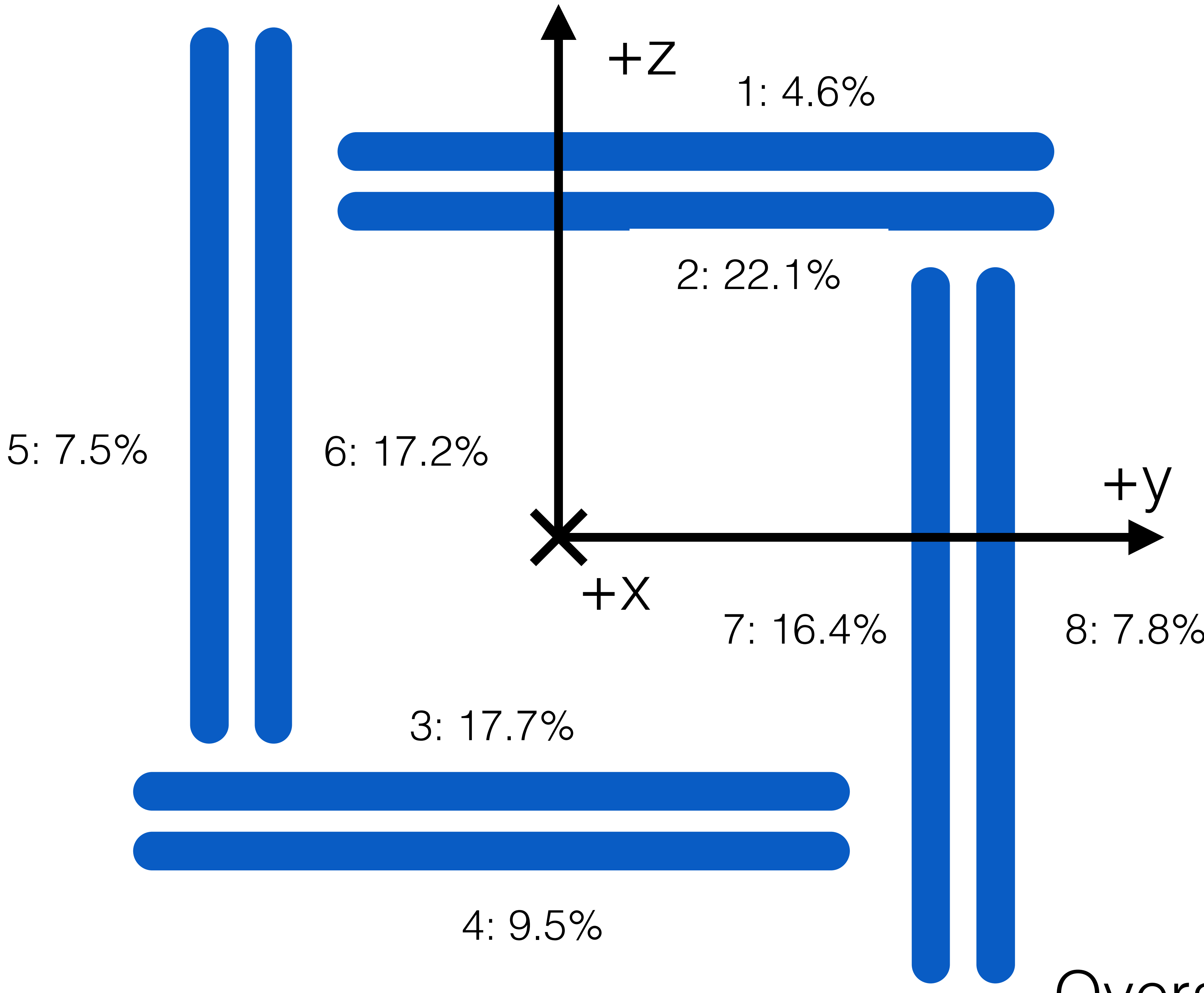
All detectors

Total successful hits	59,318
Total hits	445,732
Overall efficiency	**13.3%**
Average residual	17.4 mm

Individual detectors

Detector	Successful Hits	Total Hits	Efficiency
1	4,421	95,745	4.6%
2	21,156	95,745	22.1%
3	17,056	96,152	17.7%
4	9,100	96,152	9.5%
5	1,145	15,300	7.5%
6	2,642	15,300	17.2%
7	2,579	15,669	16.4%
8	1,219	15,669	7.8%
Total	59,318	445,732	--
Average	--	--	13.3%

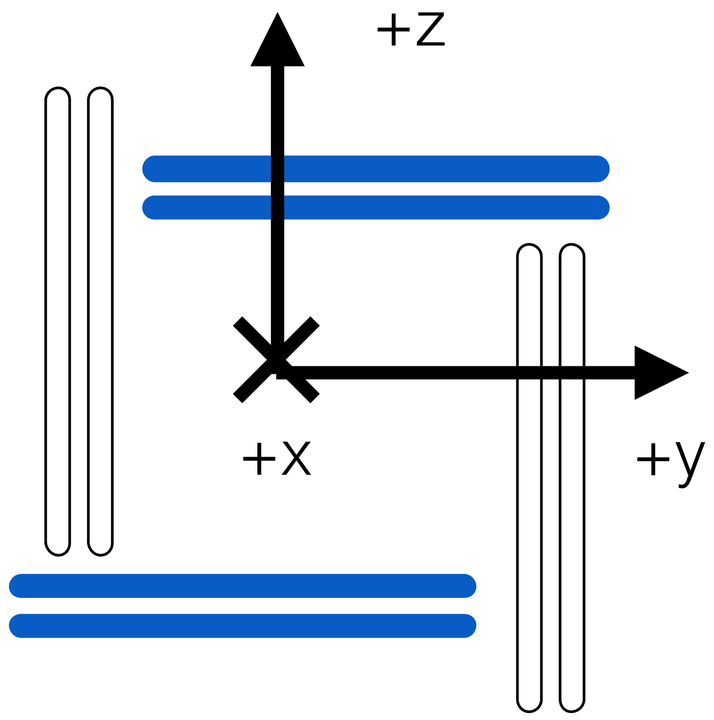
Station geometry



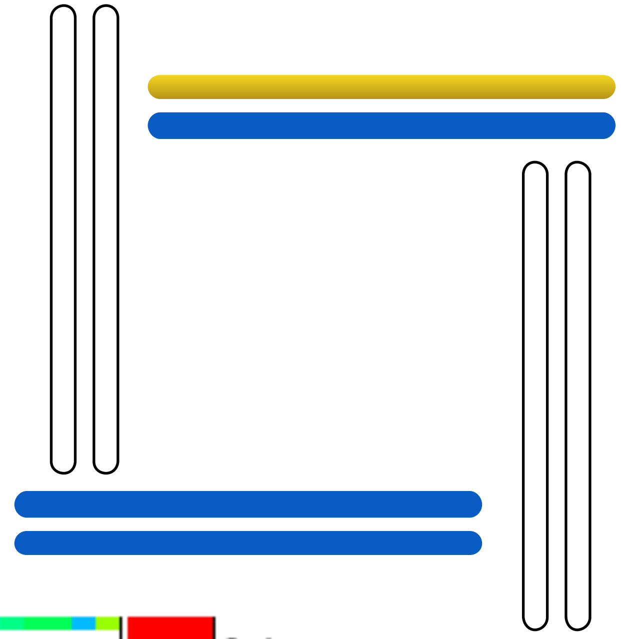
Overall: 13.3%

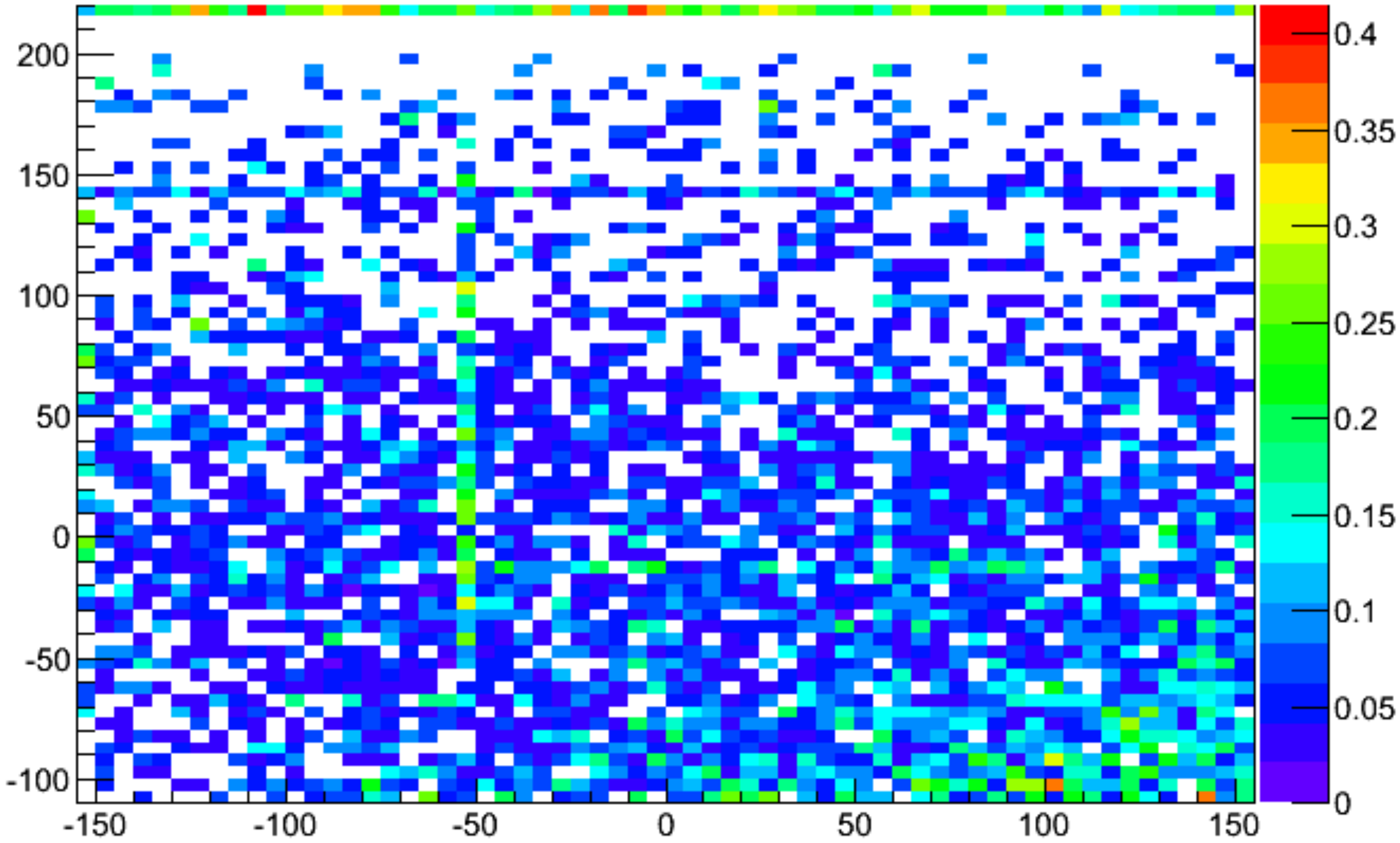
Histograms

- Bin size = 5
- Empty 4-detector station (1-4 only)
- Correspond to the xy surface of each detector
- Each pixel corresponds to the efficiency at that point

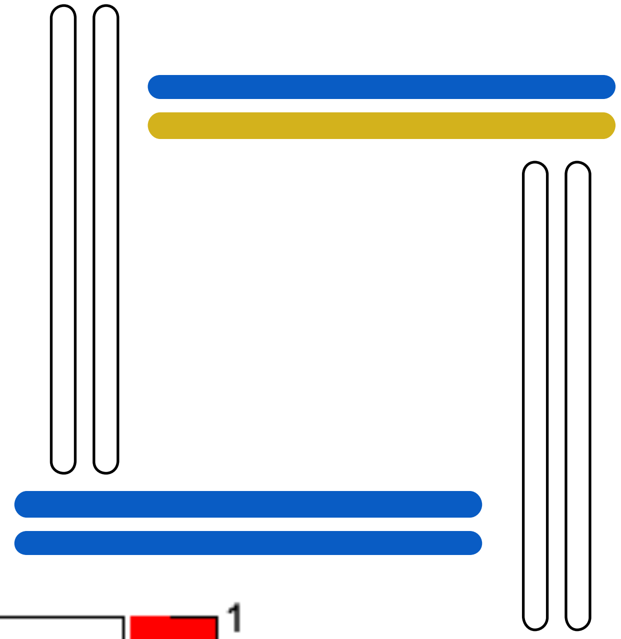


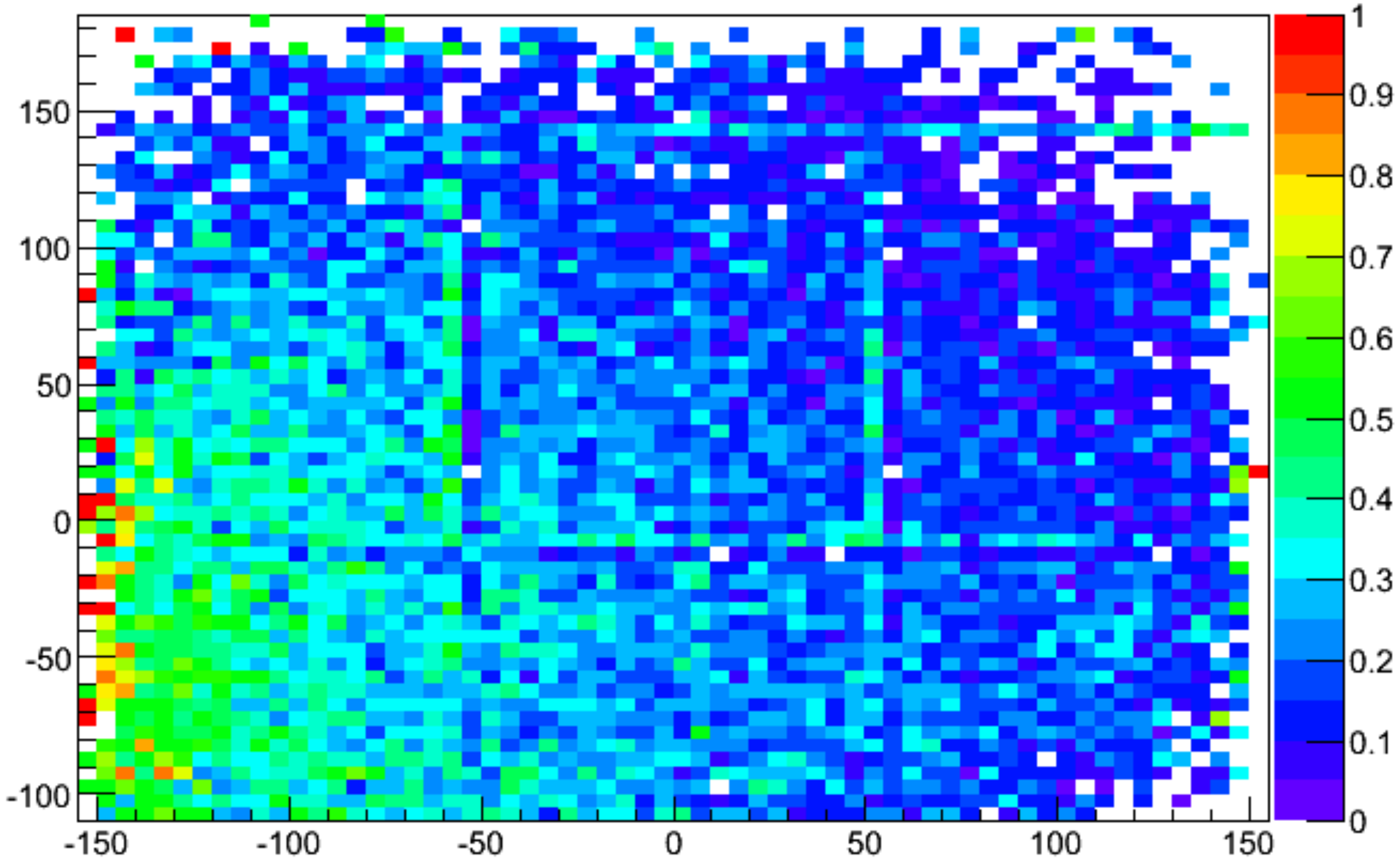
Detector 1




200
150
100
50
0
-50
-100
-150
-100
-50
0
50
100
150
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

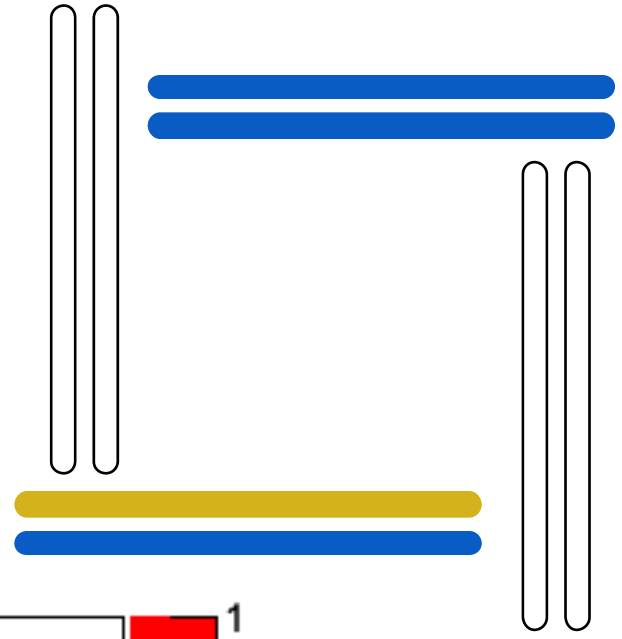
Detector 2

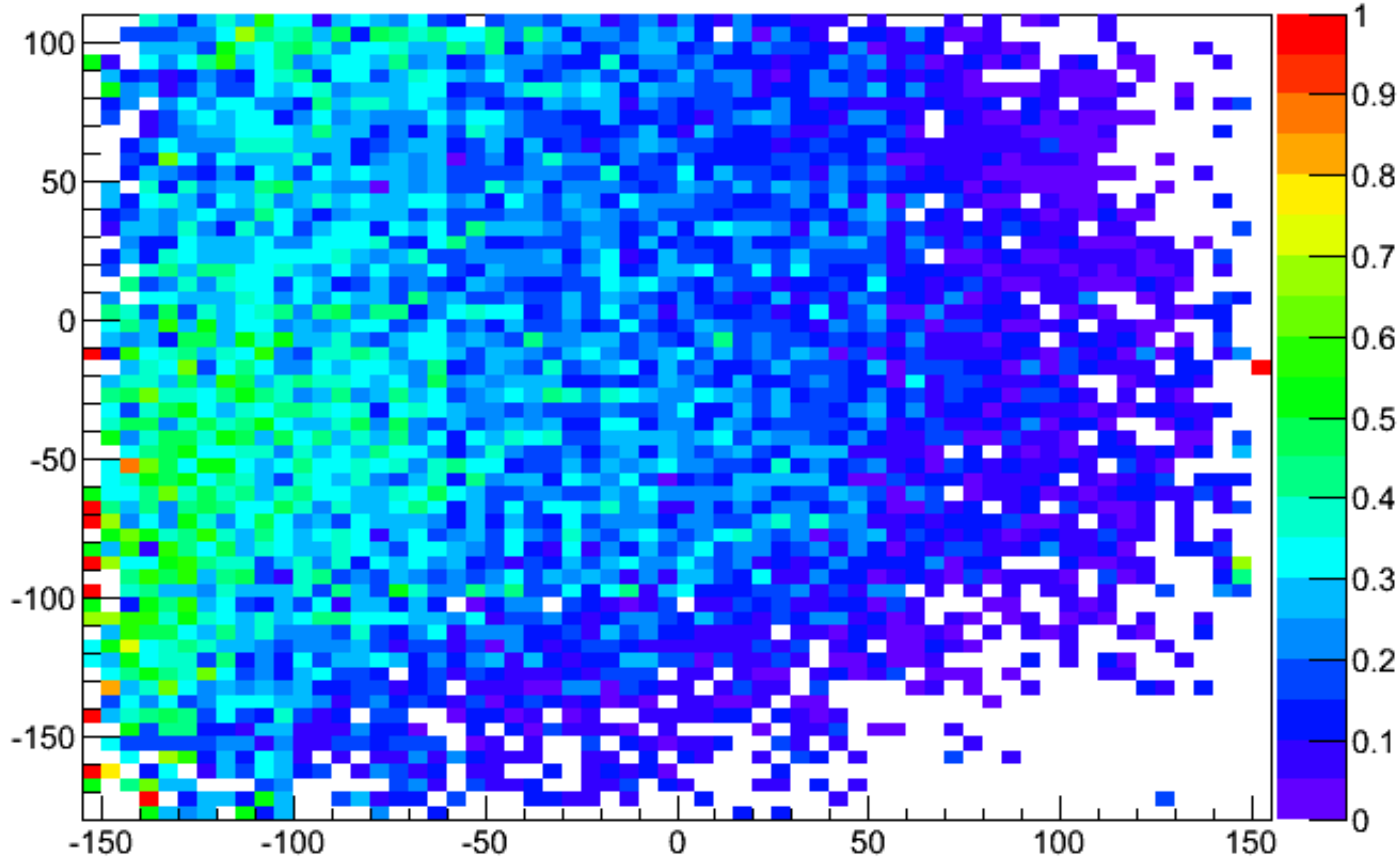




150
100
50
0
-50
-100
-150
-100
-50
0
50
100
150
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

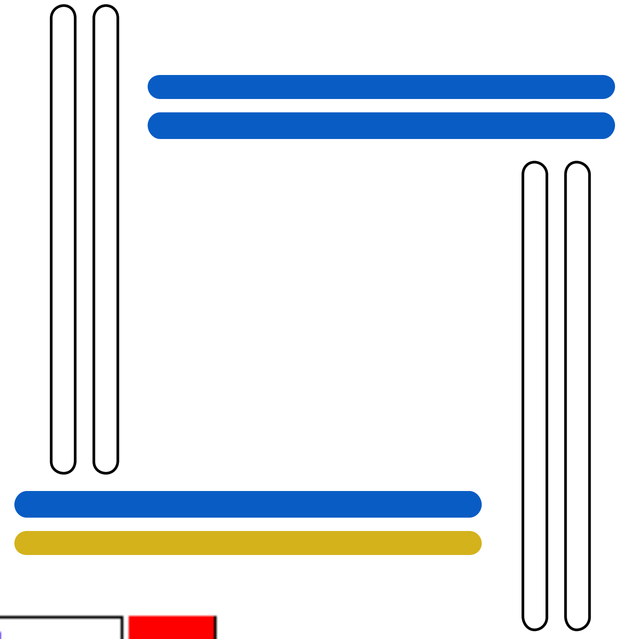
Detector 3

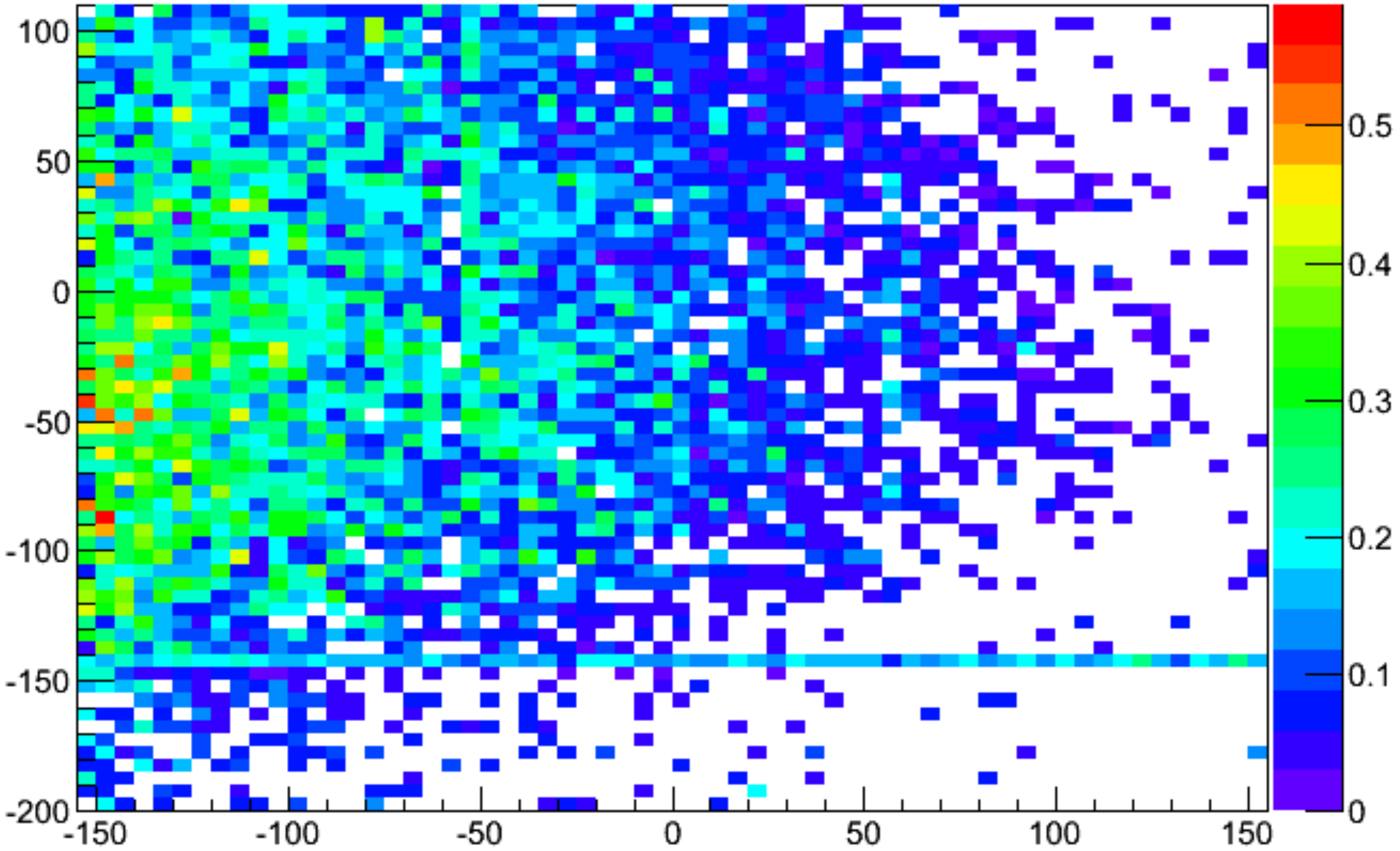




100
50
0
-50
-100
-150
-150
-100
-50
0
50
100
150
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Detector 4





Conclusion and Future Goals

- Detectors are not as efficient as hoped, will need further alignment and testing
- Noticed a lower efficiency value for detectors 1, 4, 5, and 8
- Possibly due to the extrapolation as these are all outer detectors

Acknowledgements

- Ben Locke
  - Linear fit algorithm and muon track code
- Michael Staib
  - Muon track data
- Dr. Marcus Hohlmann
  - Algorithm and research advisor

Questions?