



# Mighty Tracker Pattern Recognition (Standalone)

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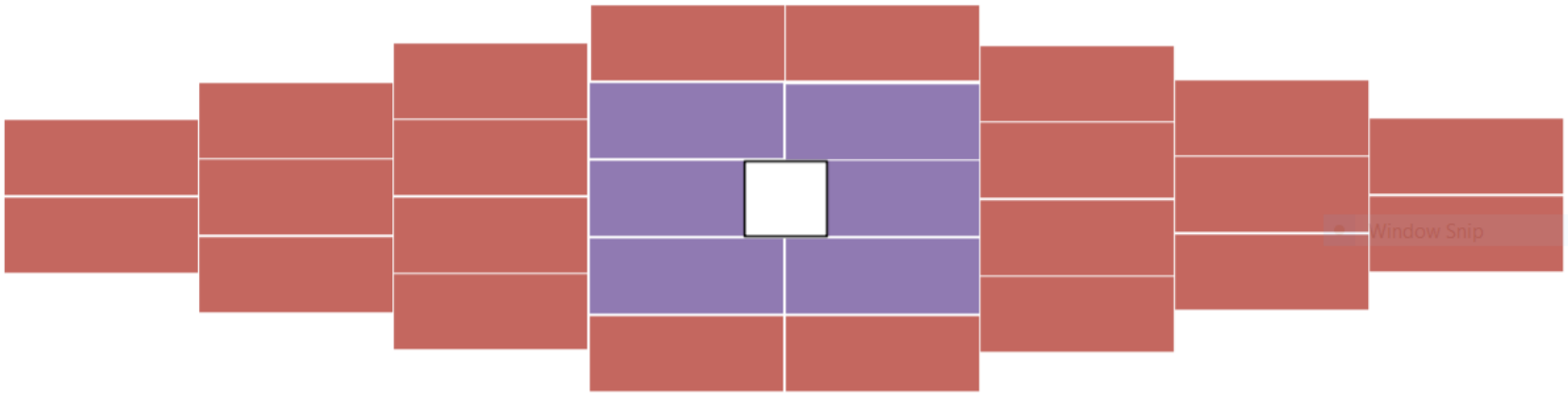
# Introduction

- This is study is a continuation of the summer student Jiazhen Tang work (presentation)
- Two samples with 21 events U2 (with and without electrons)
- Luminosity $1.5 \times 10^{34}/\mathrm{cm}^2/\mathrm{s}$
- This study considers the inner and middle sections (purple and brown)

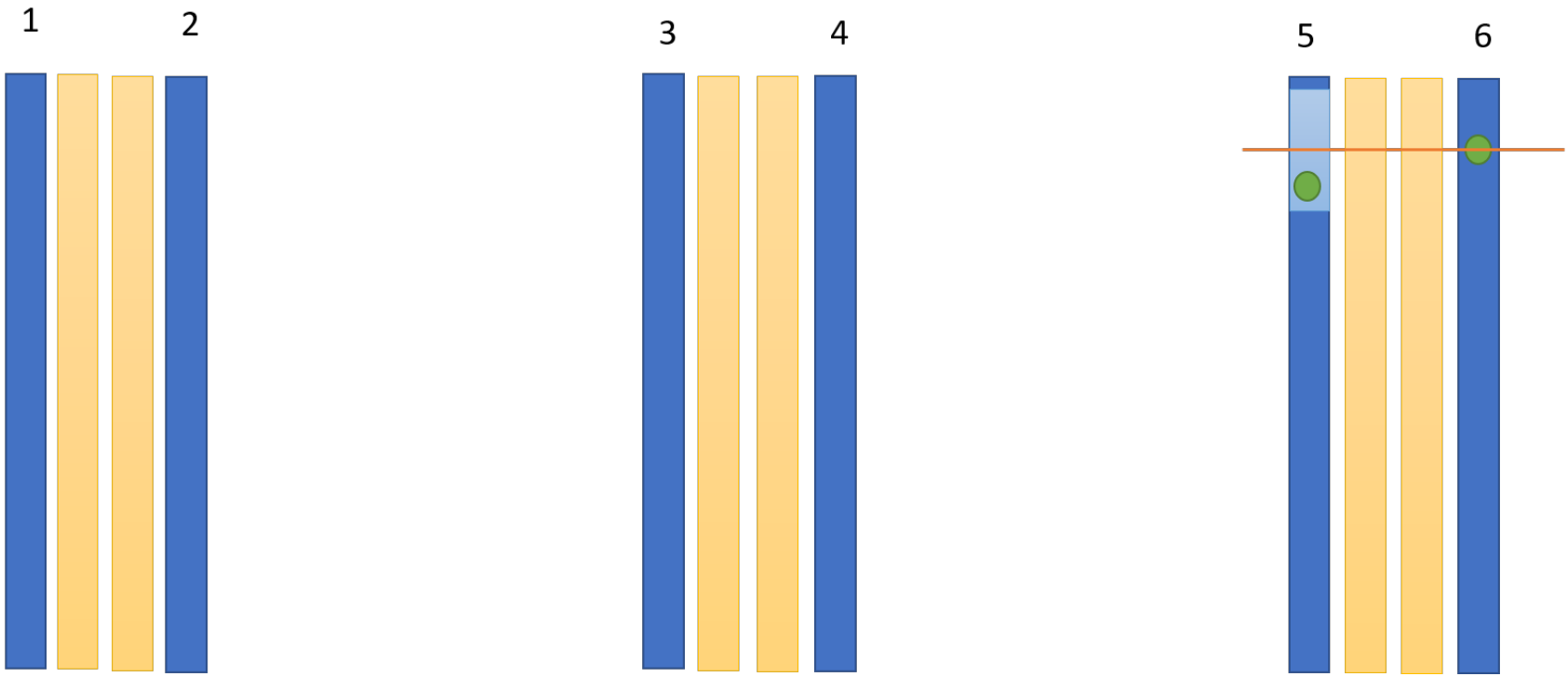


# Optimization

Optimization using the hits from selected tracks:

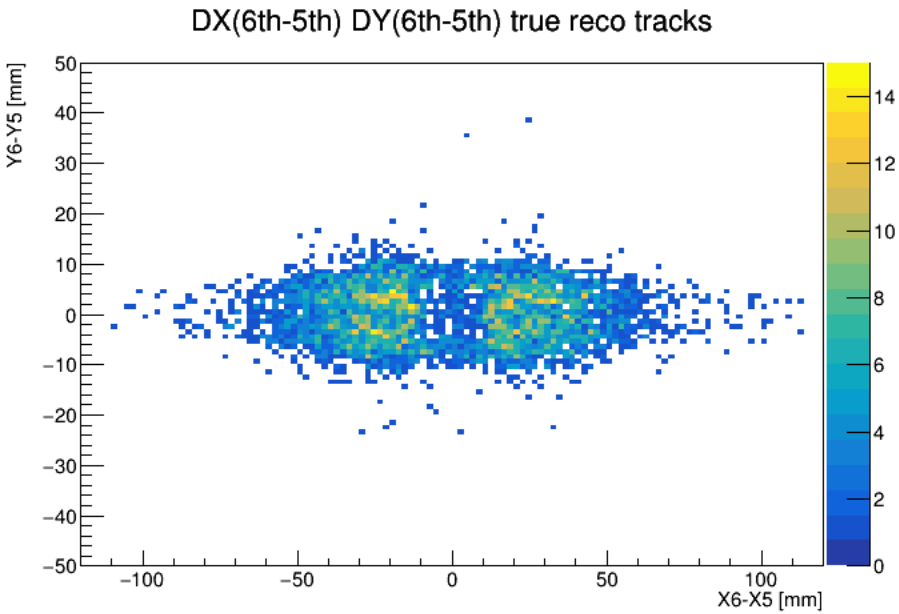
- True reconstructable track leaves hits in all 6 layers
- True track momentum above 5 GeV/c
- True track in pseudorapidity acceptance ($2 < \eta < 5$)

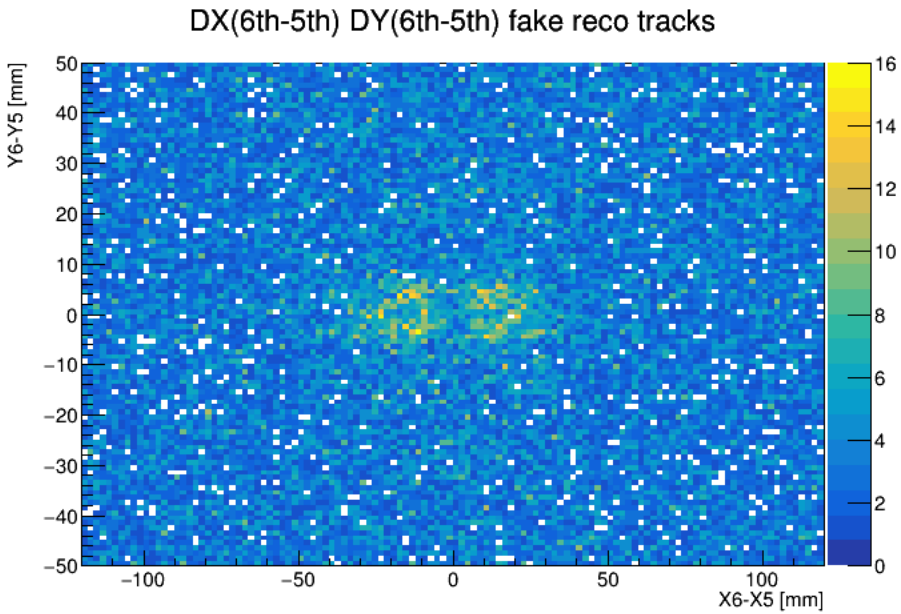
# Combination of hits between 5th-6th layers (x and Y)




- The position (X and Y coordinates) of the 6th hit is used as reference and a search window is defined

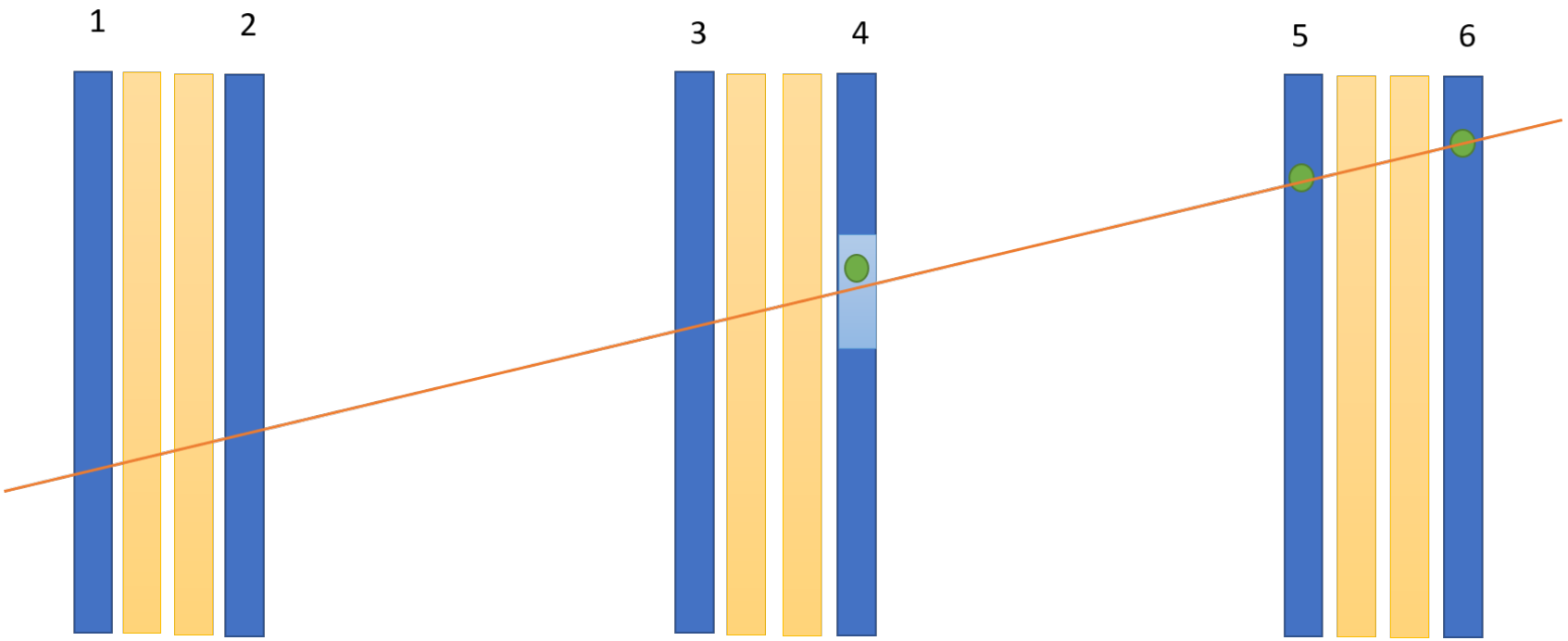
# Combination of hits between 5th-6th layers



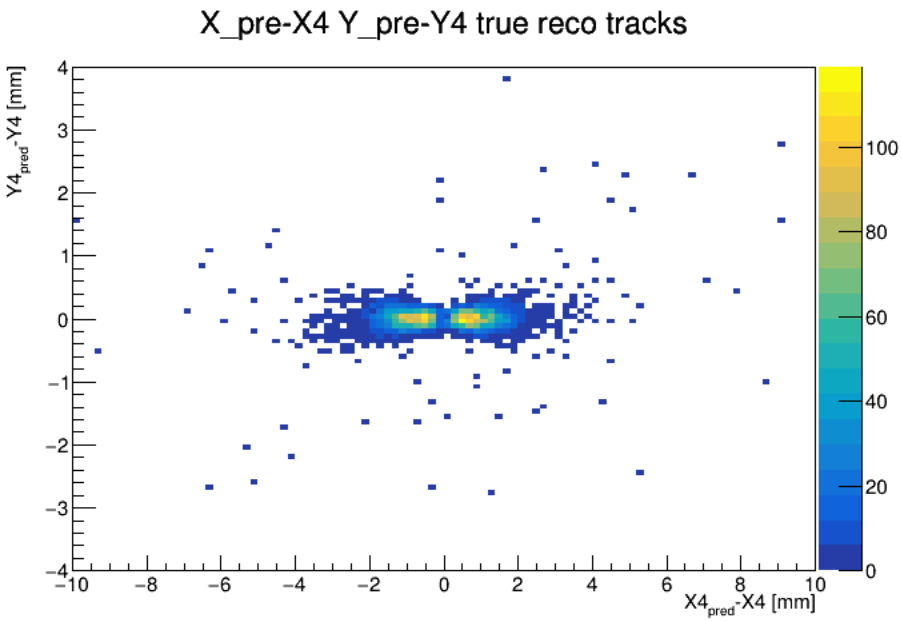

- Well defined region for the true reconstructed tracks
- Limits defined as $\Delta x < 110$ mm and $\Delta y < 15$ mm

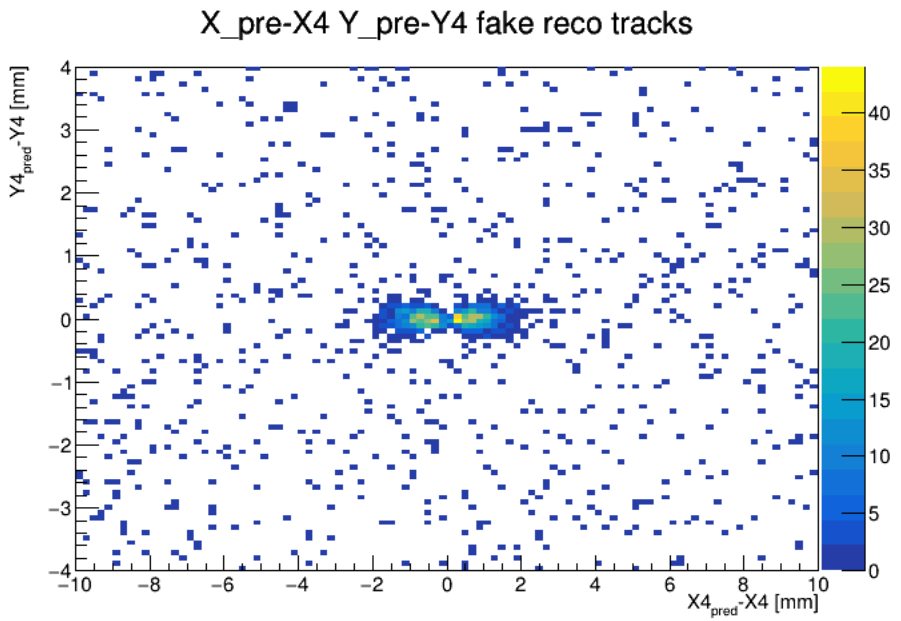
# Combination of hits between 4th-5th-6th layers (x and Y)




- Linear extrapolation using the information of the 5th-6th hits is performed to predict the position on the 4th layer (X and Y coordinates)

# Combination of hits between 4th-5th-6th layers



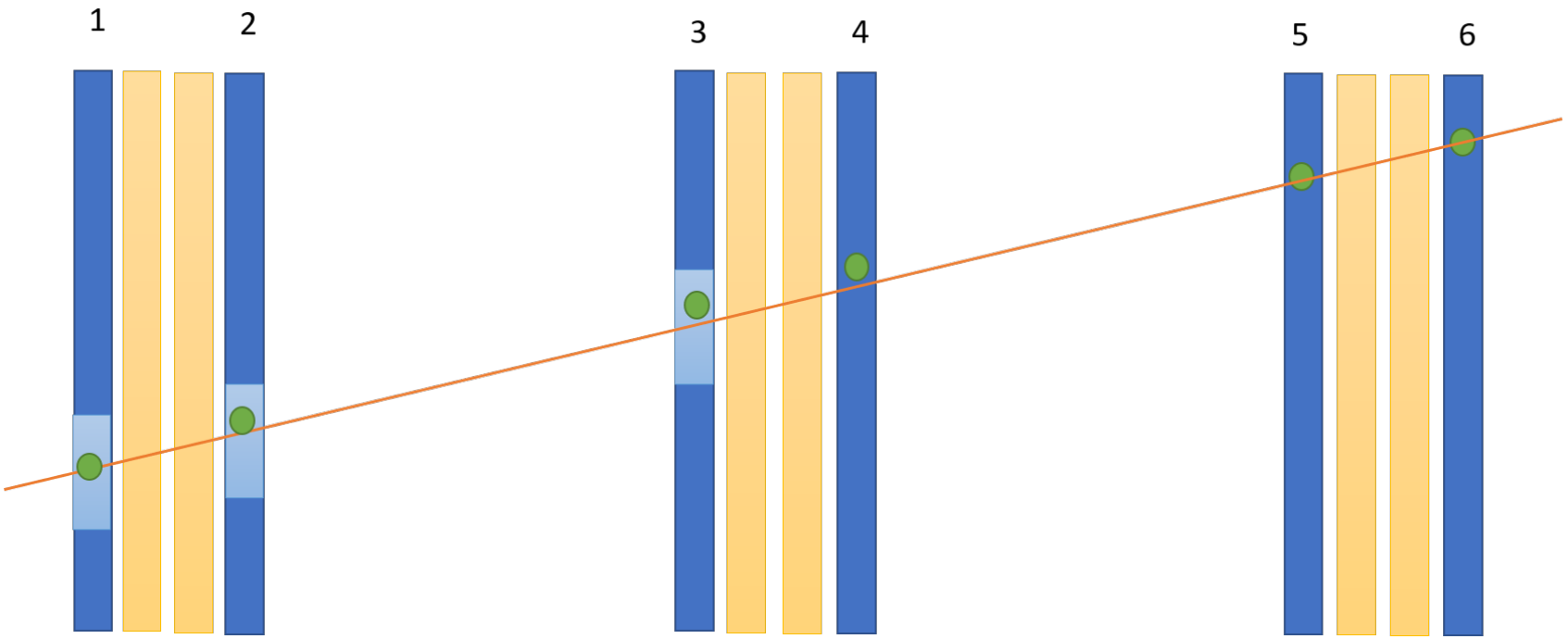




- Linear extrapolation from the hits in the 5th and 6th layers:

$$y_{predicted} = (685.0/209.0) * Y5 - (476.0/209.0) * Y6$$

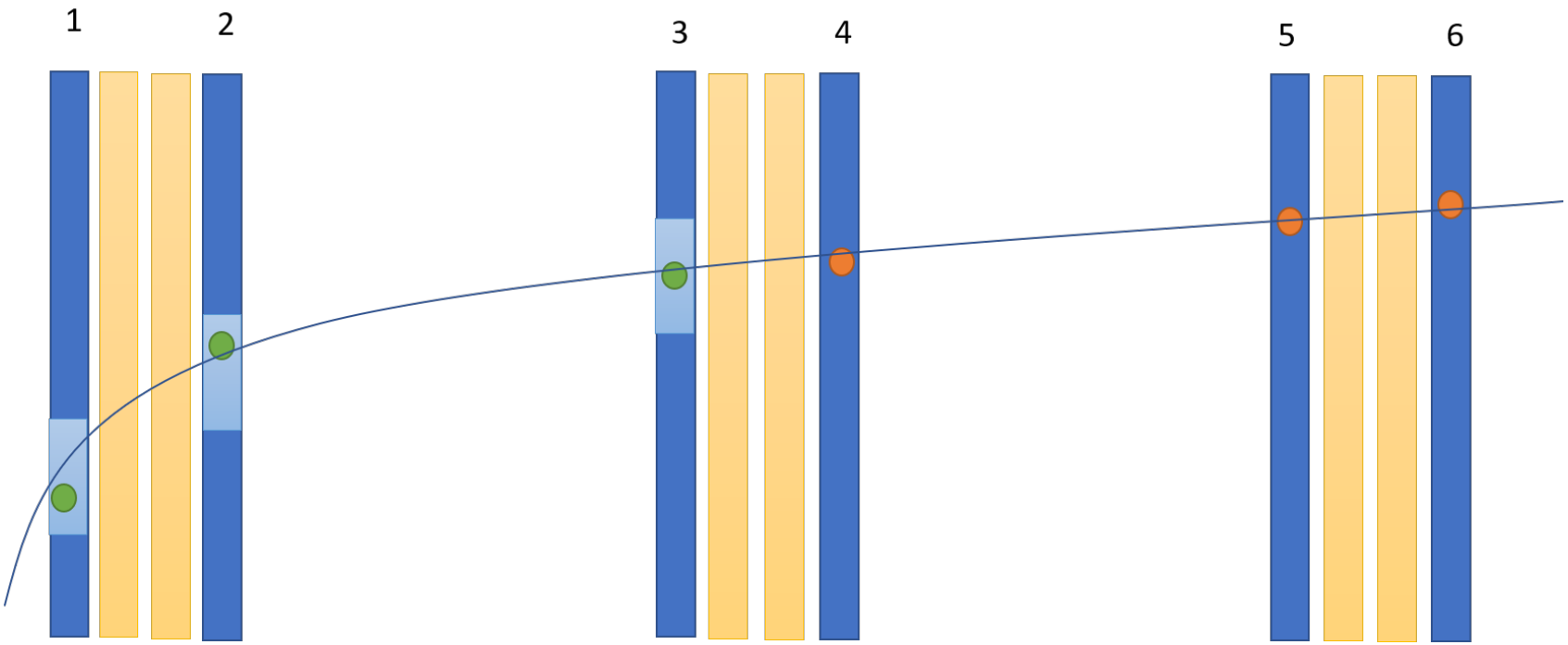
  defined in a similar way for X.
- Limits defined as $\Delta x < 4$ mm and $\Delta y < 0.7$ mm
- Y predictions for the previous layers (1st-2nd-3th) were also estimated in the same way.

# Combination of hits between 1st-2nd-3rd-4th-5th-6th layers (Y)



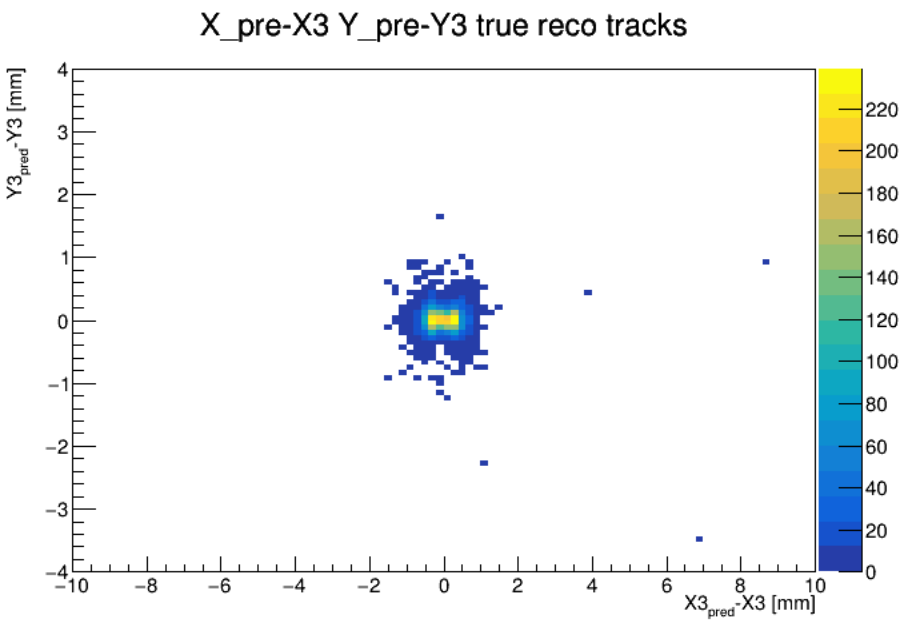

- For the Y coordinate, a linear extrapolation using the information of the 5th-6th hits is performed to predict the position on the 1st-2nd-3rd layers

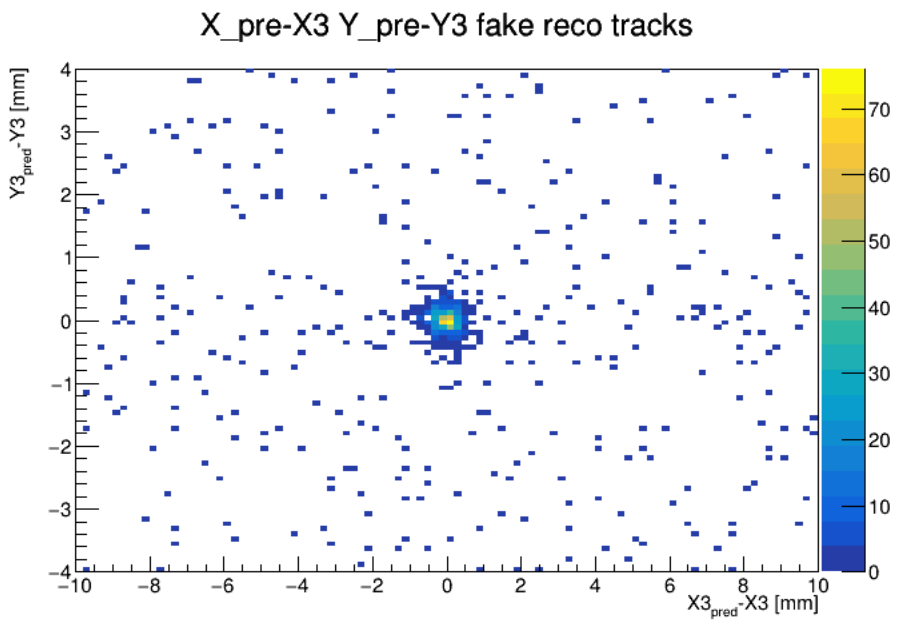
# Combination of hits between 1st-2nd-3rd-4th-5th-6th layers (X)




- Parabolic approximation to predict the X coordinate ($Z = aX^2 + bX + c$)
- The minima is requested to be before the first layer and 4-5-6 hits are requested to be on the same side of the parabola

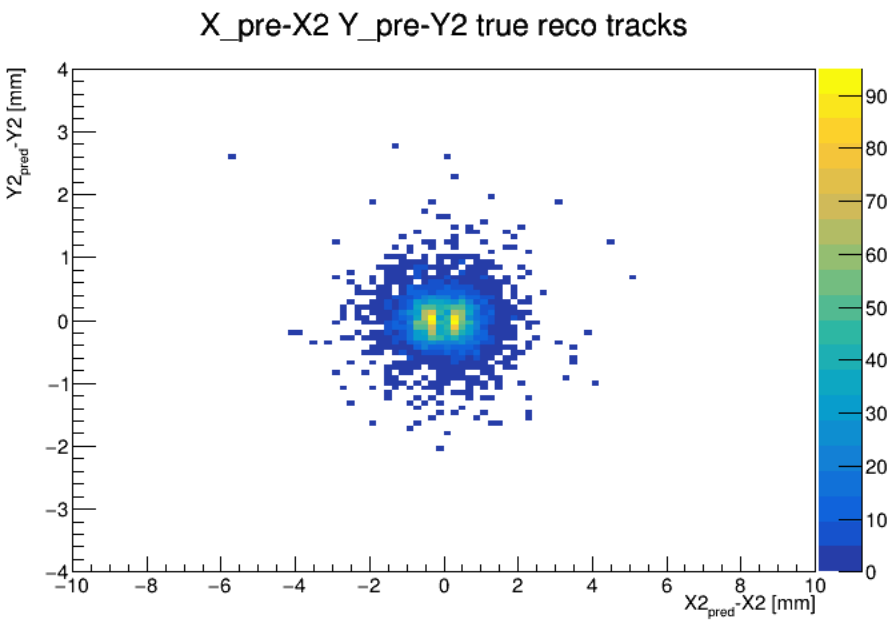
# Combination of hits between 1st-2nd-**3rd**-4th-5th-6th layers

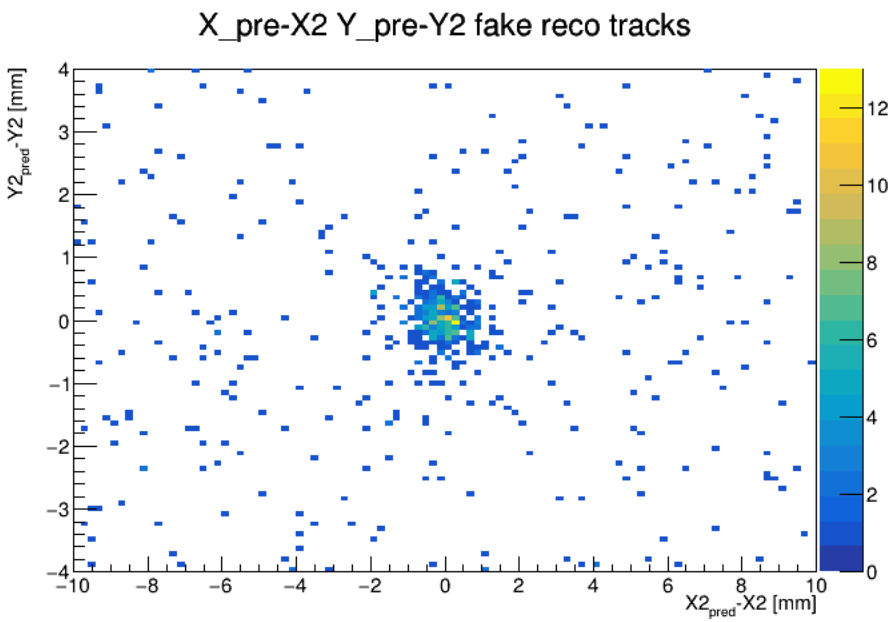



- Limits defined as $\Delta Y < 0.80$ mm and $\Delta X < 1.5$ mm

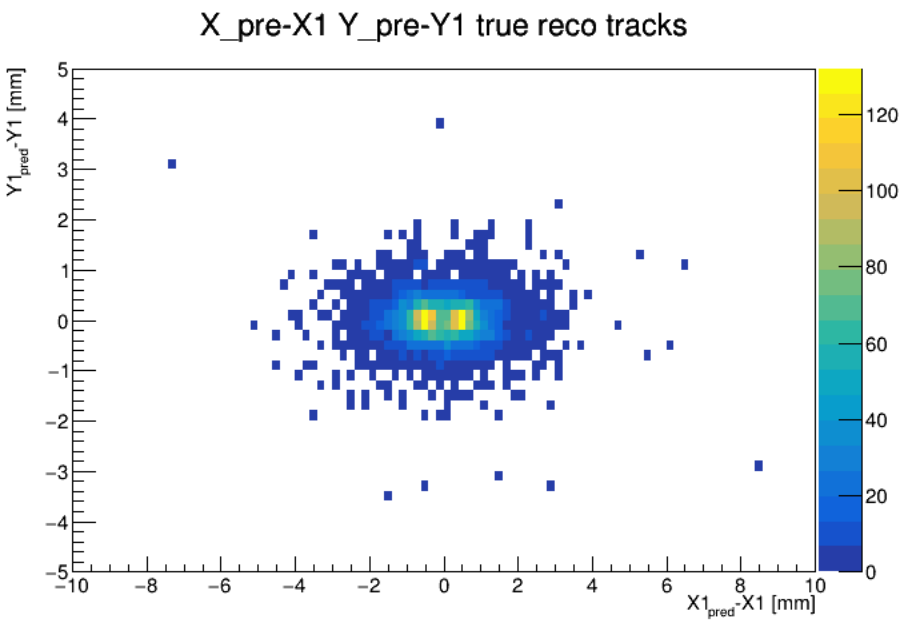
# Combination of hits between 1st-**2nd**-3rd-4th-5th-6th layers

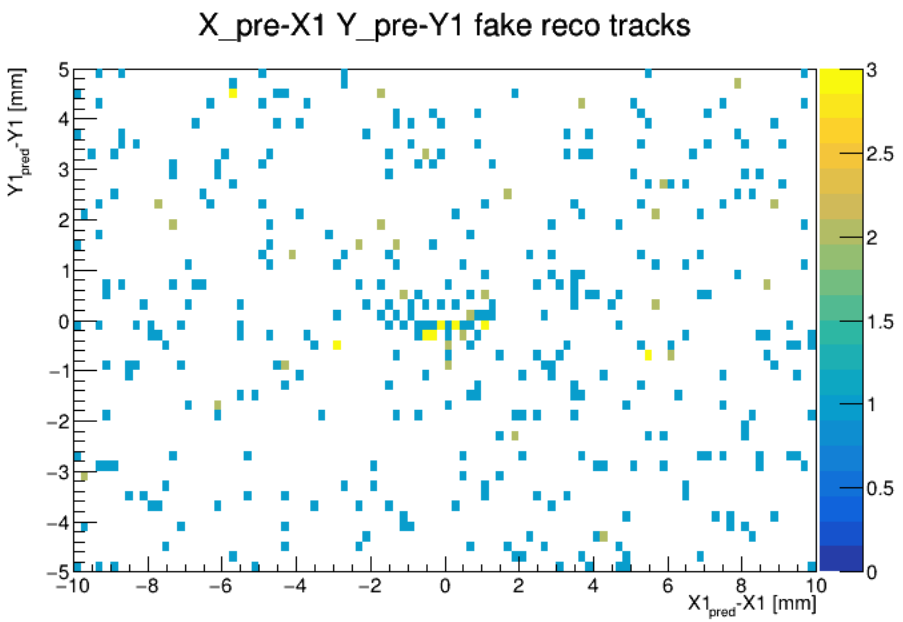



- Limits defined as $\Delta Y < 1.5$ mm and $\Delta X < 3.0$ mm

# Combination of hits between **1st**-2nd-3rd-4th-5th-6th layers

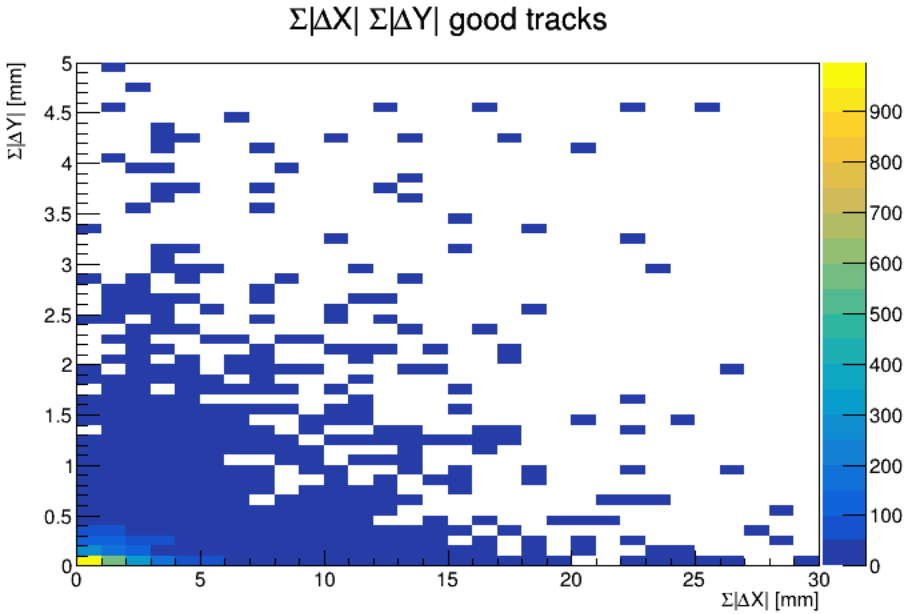


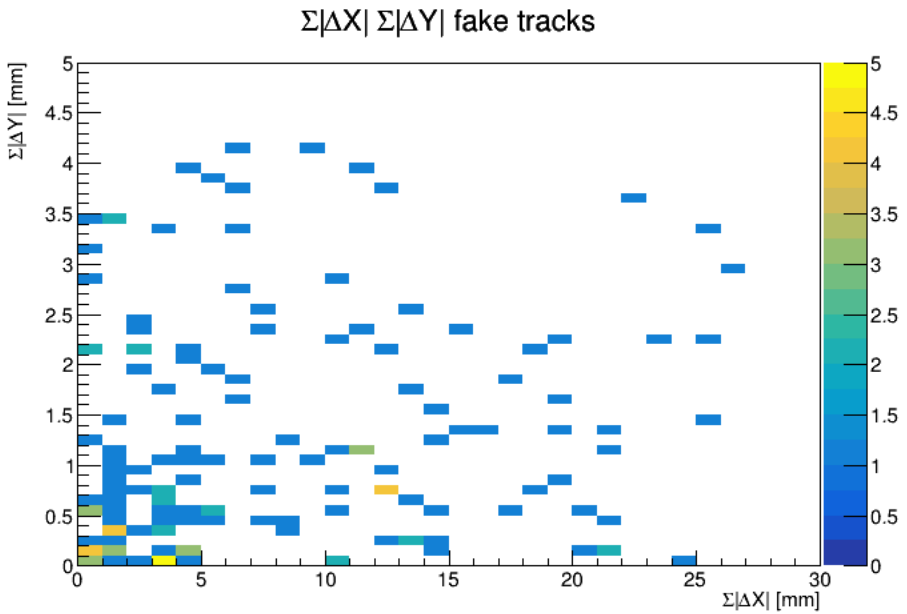




- Limits defined as $\Delta Y < 2.0$ mm and $\Delta X < 5.0$ mm

# Additional selection (SX and SY)

- Optimized using the $\sum_{i=1}^{5} |Y_i^{pred} - Y_i|$ (SY) and $\sum_{i=1}^{5} |X_i^{pred} - X_i|$ (SX)




The tables on the next slides will show the efficiencies and fake rates for 4 possible selections:

- No requirements on SX and SY
- SX $<$ 10 mm and SY $<$ 2 mm
- SX $<$ 15 mm and SY $<$ 3 mm
- SX $<$ 20 mm and SY $<$ 4 mm

# Efficiency and fake rate comparison for tracks with p$>$ 5GeV and 2$<\eta<$5

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 5 | 1 | 16.2 | 10 | 2 | 89.6 | 4560/5089 | 1.6 | 76 |
| 5 | 1 | 0.0 | 10 | 2 | 93.0 | 3968/4266 | 1.7 | 68 |
| 5 | 1 | 16.2 | 15 | 3 | 93.7 | 4767/5089 | 2.4 | 116 |
| 5 | 1 | 0.0 | 15 | 3 | 95.9 | 4091/4266 | 2.4 | 102 |
| 5 | 1 | 16.2 | 20 | 4 | 94.9 | 4832/5089 | 2.8 | 138 |
| 5 | 1 | 0.0 | 20 | 4 | 96.7 | 4126/4266 | 2.8 | 119 |
| 5 | 1 | 16.2 | - | - | 96.3 | 4902/5089 | 3.1 | 156 |
| 5 | 1 | 0.0 | - | - | 97.5 | 4159/4266 | 3.1 | 131 |

Table: Comparison for true tracks with momentum $>$ 5 GeV and in the acceptance(eta) using samples with and without electrons

- A reconstructable true track has one hit in each layer, p$>$ 5GeV and 2$<\eta<$5.
- The efficiency numerator is the number of reconstructed tracks which correspond to a MC particle

# Efficiency and fake rate comparison for all tracks (no momentum or $\eta$ requirement)

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 26.9 | 10 | 2 | 65.9 | 6122/9292 | 9.4 | 636 |
| 0 | 0 | 0.0 | 10 | 2 | 74.8 | 5079/6788 | 4.4 | 236 |
| 0 | 0 | 26.9 | 15 | 3 | 72.8 | 6765/9292 | 11.0 | 834 |
| 0 | 0 | 0.0 | 15 | 3 | 80.7 | 5476/6788 | 5.5 | 320 |
| 0 | 0 | 26.9 | 20 | 4 | 76.4 | 7098/9292 | 11.6 | 933 |
| 0 | 0 | 0.0 | 20 | 4 | 83.6 | 5676/6788 | 6.0 | 365 |
| 0 | 0 | 26.9 | - | - | 80.0 | 7430/9292 | 12.3 | 1039 |
| 0 | 0 | 0.0 | - | - | 86.5 | 5871/6788 | 6.3 | 395 |

Table: Comparison for true tracks without momentum and eta requirements using samples with and without electrons

- A reconstructable true track has one hit in each layer (no momentum or $\eta$ requirement)
- The efficiency numerator is the number of reconstructed tracks which correspond to a MC particle

# Efficiency and fake rate comparison for tracks with p$>$ 20GeV and 2$<\eta<$5

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 20 | 1 | 7.8 | 10 | 2 | 97.4 | 862/885 | 1.0 | 9 |
| 20 | 1 | 0.0 | 10 | 2 | 98.2 | 801/816 | 1.1 | 9 |
| 20 | 1 | 7.8 | 15 | 3 | 97.9 | 866/885 | 1.3 | 11 |
| 20 | 1 | 0.0 | 15 | 3 | 98.2 | 801/816 | 1.2 | 10 |
| 20 | 1 | 7.8 | 20 | 4 | 98.1 | 868/885 | 1.5 | 13 |
| 20 | 1 | 0.0 | 20 | 4 | 98.3 | 802/816 | 1.5 | 12 |
| 20 | 1 | 7.8 | - | - | 98.2 | 869/885 | 1.6 | 14 |
| 20 | 1 | 0.0 | - | - | 98.3 | 802/816 | 1.6 | 13 |

Table: Comparison for true tracks with momentum $>$ 20 GeV and in the acceptance(eta) using samples with and without electrons

- A reconstructable true track has one hit in each layer, p$>$ 20GeV and 2$<\eta<$5
- The efficiency numerator is the number of reconstructed tracks which correspond to a MC particle

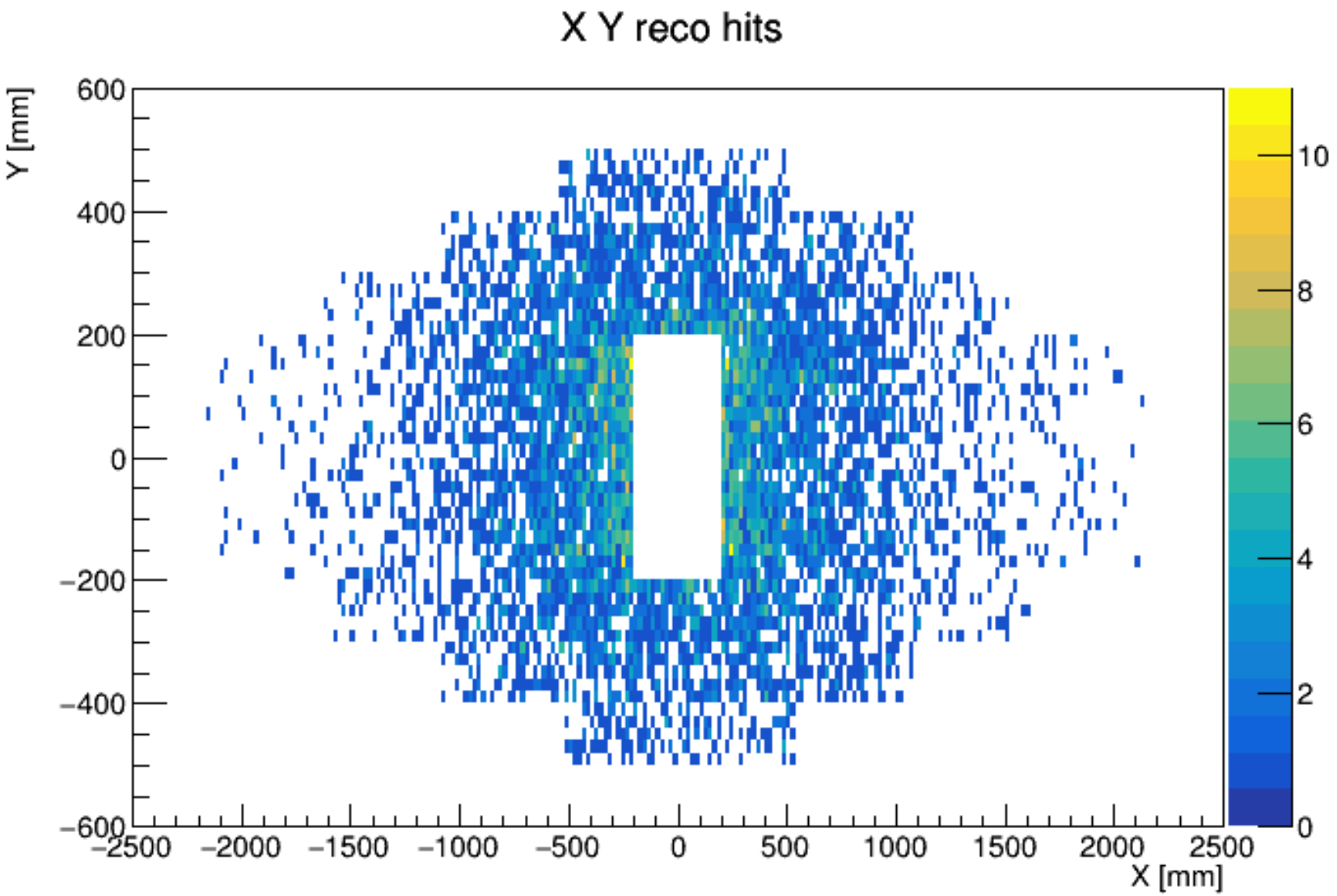
# Summary

- This algorithm has 96.3% efficiency and 3.1% (with p$>$ 5GeV and $\eta$ requirements)
- Without p and $\eta$ requirements, the performance is worse (80.0% efficiency and 12.3% fake rate)
- Those figures already represent an improvement with respect to the previous results
  - 89% eff. 12.9% Fake Rate with tight requirements with p and $\eta$ preselection
  - 93.9% eff. 15.7% Fake rate with looser requirements with p and $\eta$ preselection
- Possible to further reduce the fake rate using $\sum_{i=1}^{5} |Y_i^{pred} - Y_i|$ and $\sum_{i=1}^{5} |X_i^{pred} - X_i|$ down to 1.6% with $\sim$ 90% eff.
- Next steps:
  - Optimization of the search windows without $\eta$ and momentum requirements
  - Performance removing one layer
  - More statistics
  - Aiming for an internal note early next year
  - Further ideas?

Thank you for your attention!

# Backup slides

# Hits on the 6th layer



| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 21.9 | 10 | 2 | 69.3 | 5190/7492 | 3.6 | 192 |
| 0 | 1 | 21.9 | 15 | 3 | 76.5 | 5729/7492 | 4.7 | 282 |
| 0 | 1 | 21.9 | 20 | 4 | 80.0 | 5993/7492 | 5.2 | 331 |
| 0 | 1 | 21.9 | - | - | 83.7 | 6269/7492 | 5.6 | 373 |
| 5 | 1 | 16.2 | 10 | 2 | 89.6 | 4560/5089 | 1.6 | 76 |
| 5 | 1 | 16.2 | 15 | 3 | 93.7 | 4767/5089 | 2.4 | 116 |
| 5 | 1 | 16.2 | 20 | 4 | 94.9 | 4832/5089 | 2.8 | 138 |
| 5 | 1 | 16.2 | - | - | 96.3 | 4902/5089 | 3.1 | 156 |
| 20 | 1 | 7.8 | 10 | 2 | 97.4 | 862/885 | 1.0 | 9 |
| 20 | 1 | 7.8 | 15 | 3 | 97.9 | 866/885 | 1.3 | 11 |
| 20 | 1 | 7.8 | 20 | 4 | 98.1 | 868/885 | 1.5 | 13 |
| 20 | 1 | 7.8 | - | - | 98.2 | 869/885 | 1.6 | 14 |

Table: PID with acceptance(eta) requirement.

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 26.9 | 10 | 2 | 65.9 | 6122/9292 | 9.4 | 636 |
| 0 | 0 | 26.9 | 15 | 3 | 72.8 | 6765/9292 | 11.0 | 834 |
| 0 | 0 | 26.9 | 20 | 4 | 76.4 | 7098/9292 | 11.6 | 933 |
| 0 | 0 | 26.9 | - | - | 80.0 | 7430/9292 | 12.3 | 1039 |
| 5 | 0 | 21.3 | 10 | 2 | 88.0 | 5425/6162 | 2.2 | 124 |
| 5 | 0 | 21.3 | 15 | 3 | 92.3 | 5690/6162 | 3.3 | 193 |
| 5 | 0 | 21.3 | 20 | 4 | 94.0 | 5790/6162 | 3.8 | 230 |
| 5 | 0 | 21.3 | - | - | 95.4 | 5879/6162 | 4.4 | 268 |
| 20 | 0 | 15.0 | 10 | 2 | 95.3 | 951/998 | 0.9 | 9 |
| 20 | 0 | 15.0 | 15 | 3 | 96.1 | 959/998 | 1.1 | 11 |
| 20 | 0 | 15.0 | 20 | 4 | 96.7 | 965/998 | 1.3 | 13 |
| 20 | 0 | 15.0 | - | - | 97.1 | 969/998 | 1.4 | 14 |

Table: PID without acceptance(eta) requirement.

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 0.0 | 10 | 2 | 76.6 | 4483/5852 | 2.5 | 116 |
| 0 | 1 | 0.0 | 15 | 3 | 83.1 | 4862/5852 | 3.3 | 165 |
| 0 | 1 | 0.0 | 20 | 4 | 86.2 | 5044/5852 | 3.8 | 197 |
| 0 | 1 | 0.0 | - | - | 89.2 | 5222/5852 | 3.9 | 212 |
| 5 | 1 | 0.0 | 10 | 2 | 93.0 | 3968/4266 | 1.7 | 68 |
| 5 | 1 | 0.0 | 15 | 3 | 95.9 | 4091/4266 | 2.4 | 102 |
| 5 | 1 | 0.0 | 20 | 4 | 96.7 | 4126/4266 | 2.8 | 119 |
| 5 | 1 | 0.0 | - | - | 97.5 | 4159/4266 | 3.1 | 131 |
| 20 | 1 | 0.0 | 10 | 2 | 98.2 | 801/816 | 1.1 | 9 |
| 20 | 1 | 0.0 | 15 | 3 | 98.2 | 801/816 | 1.2 | 10 |
| 20 | 1 | 0.0 | 20 | 4 | 98.3 | 802/816 | 1.5 | 12 |
| 20 | 1 | 0.0 | - | - | 98.3 | 802/816 | 1.6 | 13 |

Table: NoElectrons with acceptance(eta) requirement.

| Min. P (GeV) | Acc - | True $e^-$ (%) | SX (mm) | SY (mm) | Eff. (%) | TrueReco/ True | Fake Rate (%) | Fake - |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.0 | 10 | 2 | 74.8 | 5079/6788 | 4.4 | 236 |
| 0 | 0 | 0.0 | 15 | 3 | 80.7 | 5476/6788 | 5.5 | 320 |
| 0 | 0 | 0.0 | 20 | 4 | 83.6 | 5676/6788 | 6.0 | 365 |
| 0 | 0 | 0.0 | - | - | 86.5 | 5871/6788 | 6.3 | 395 |
| 5 | 0 | 0.0 | 10 | 2 | 93.5 | 4536/4852 | 2.0 | 93 |
| 5 | 0 | 0.0 | 15 | 3 | 96.1 | 4663/4852 | 3.0 | 143 |
| 5 | 0 | 0.0 | 20 | 4 | 96.9 | 4701/4852 | 3.4 | 165 |
| 5 | 0 | 0.0 | - | - | 97.6 | 4736/4852 | 3.7 | 182 |
| 20 | 0 | 0.0 | 10 | 2 | 98.1 | 832/848 | 1.1 | 9 |
| 20 | 0 | 0.0 | 15 | 3 | 98.1 | 832/848 | 1.2 | 10 |
| 20 | 0 | 0.0 | 20 | 4 | 98.2 | 833/848 | 1.4 | 12 |
| 20 | 0 | 0.0 | - | - | 98.2 | 833/848 | 1.5 | 13 |

Table: NoElectrons without acceptance(eta) requirement.