Reconstruction of spatial information with the 1-cell SBT prototype using a Neural Network

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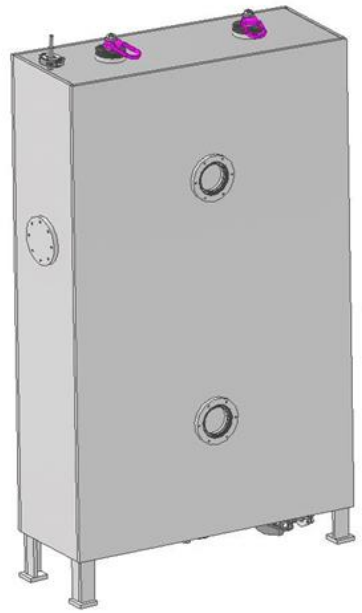
09.02.2023

1. Setup and Data

Testbeam at DESY

- A prototype SBT cell with $80 \times 120 \times 25\ cm^3$ scale.
- Each cell contains two Wavelength-Shifting Optical Modules (WOMs)
- An array of 40 silicon photomultipliers (SiPMs) per WOM to capture the photons.
- A group of 5 SiPMs signals read out.

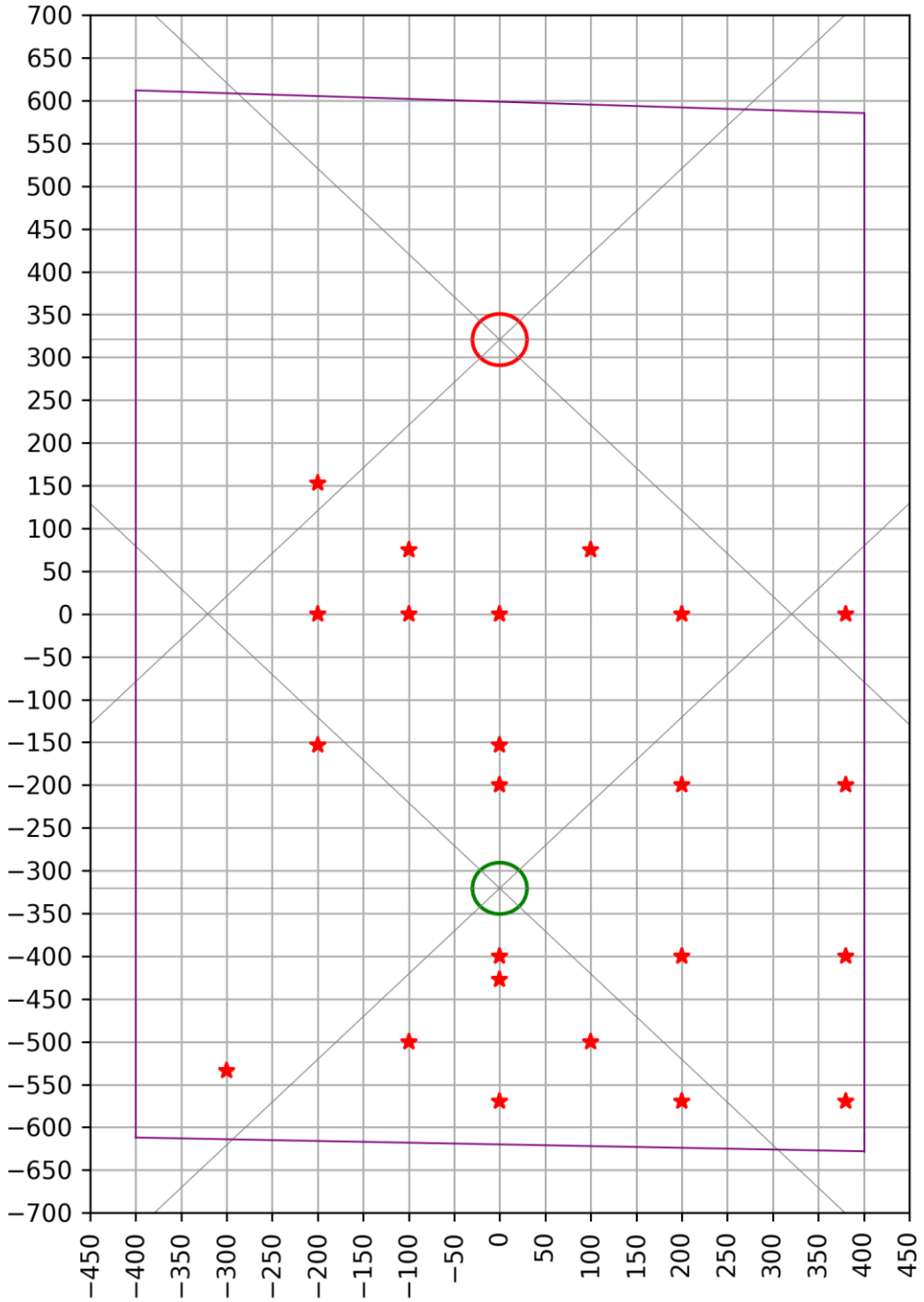


Testbeam at DESY

Box rotation	0°	±15°	±30°	±45°	±60°	±75°	±90°

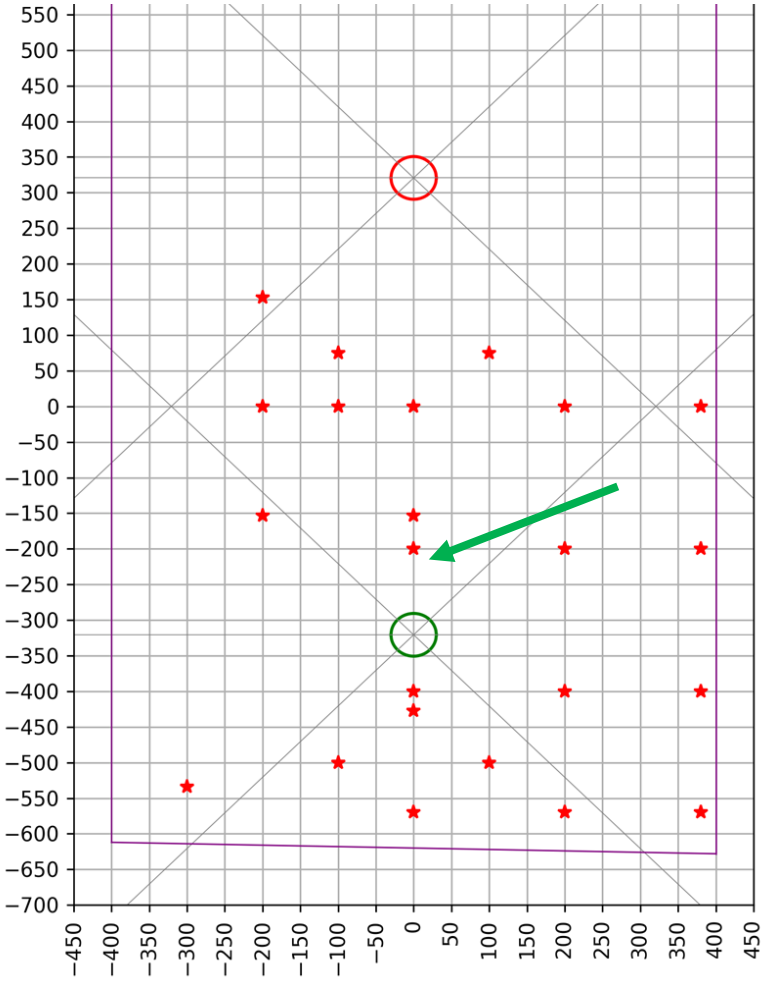
Beam Energy	1.4 GeV	2.4 GeV	3.4 GeV	4.4 GeV	5.4 GeV

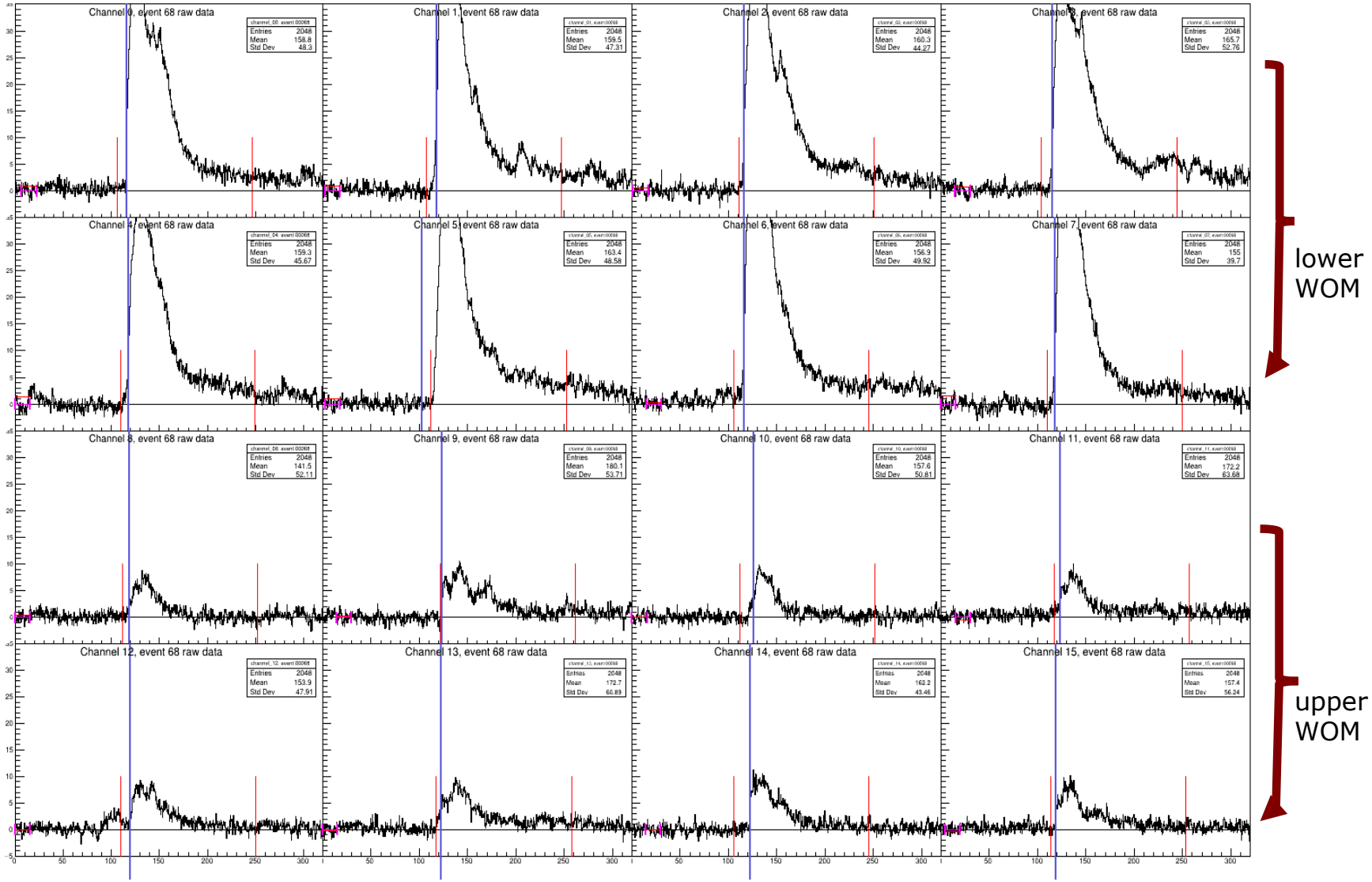
- Used Data for this presentation:
  - 23 points
  - 1.4 GeV
  - 0° degree (beams are perpendicular to the cell)
  - 10,000 events per beam position



Waveforms sample for one event

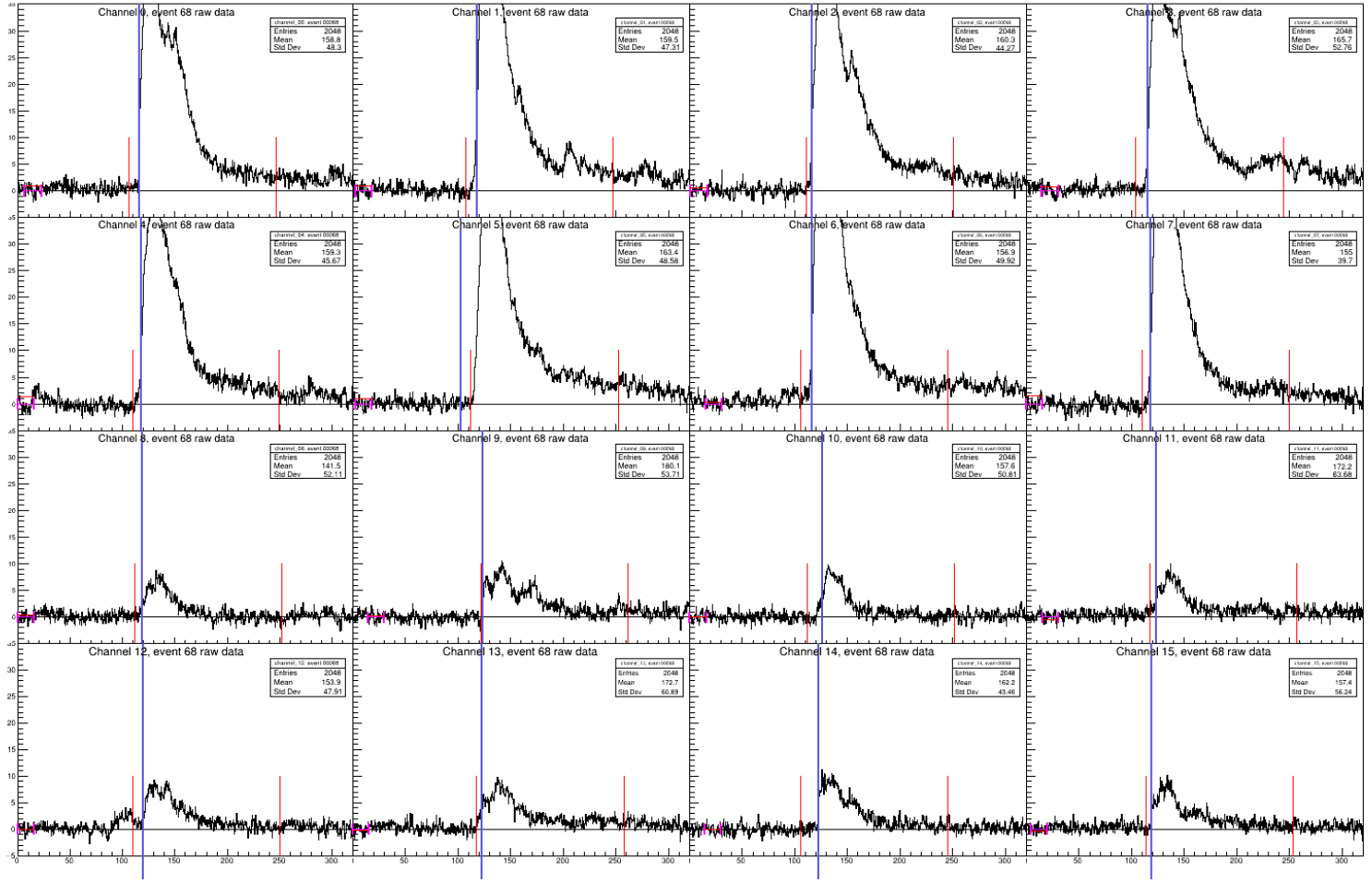
- Abscissa: Time window (320 ns)
- Ordinate: Amplitude (-5 , 35 mv)





Information from Waveforms

- Charge spectrum: integrate waveform between left and right edge of window. (red lines)
  windows determined with peak's time.
- Timing: First photons arrival time. (blue line) measured the time when signal reaches 25% of the peak.
- 16 Timings + 16 Charge spectrums(CS) = 32 features per event.



2.Neural Network: Testbeam Data

Neural Network:

- Training and Test both are on the Testbeam Data
- Data set = 23 *10000 events
- 75% to train (D_{train})
- 25% to test (D_{test})
- Mean Absolute Error (MAE)=

$$\frac{1}{2N_{D_{test}}} \sum_{i \in D_{test}} (|x - x'_i| + |y - y'_i|)$$

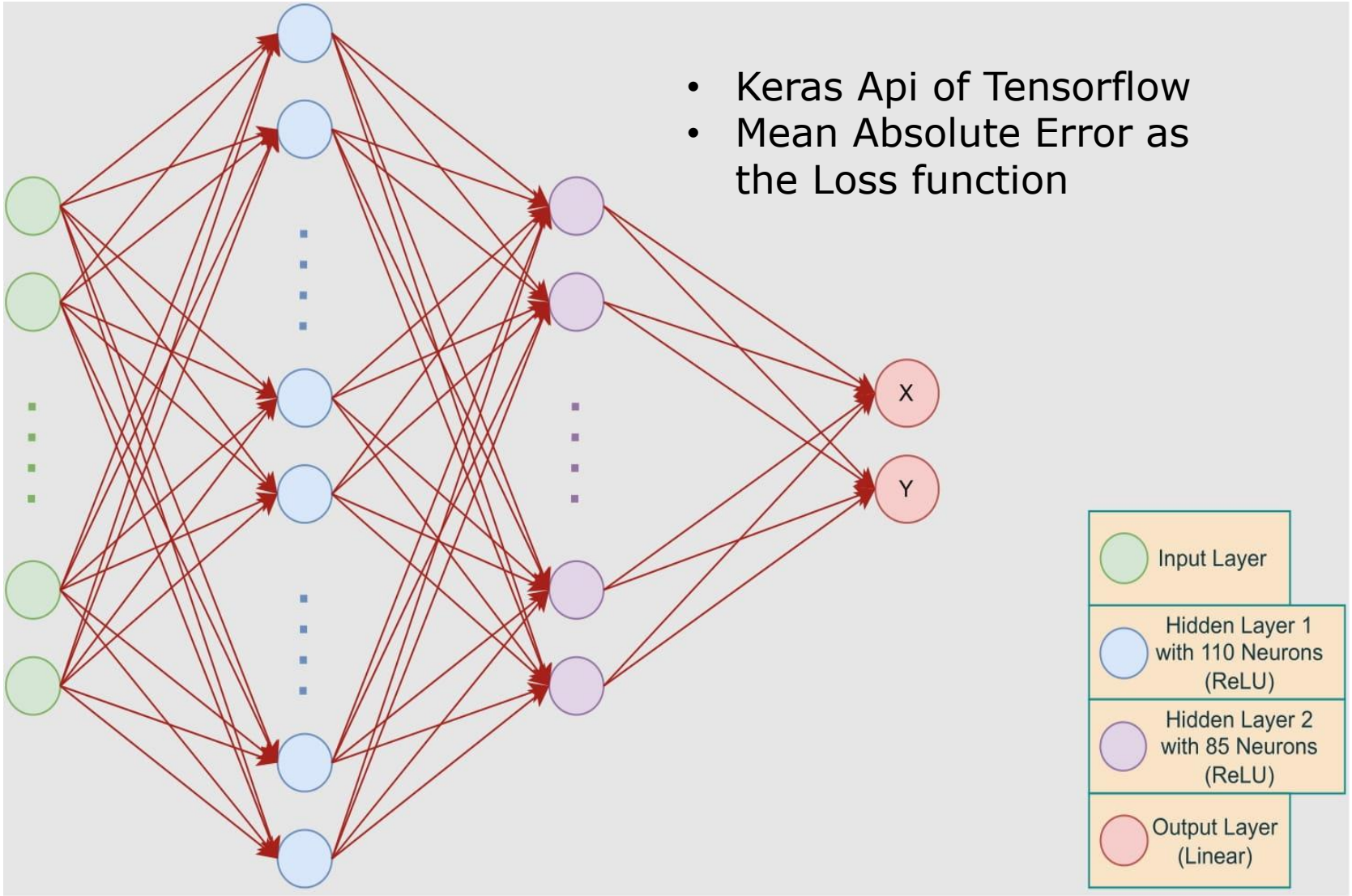
- Std Deviation (σ) =

$$\sqrt{\frac{\sum_i (x - \bar{x}_i)^2}{N}}$$

$x = true\ value\ ,\ x' = predicted\ value$

$\bar{x} = mean\ of\ x$

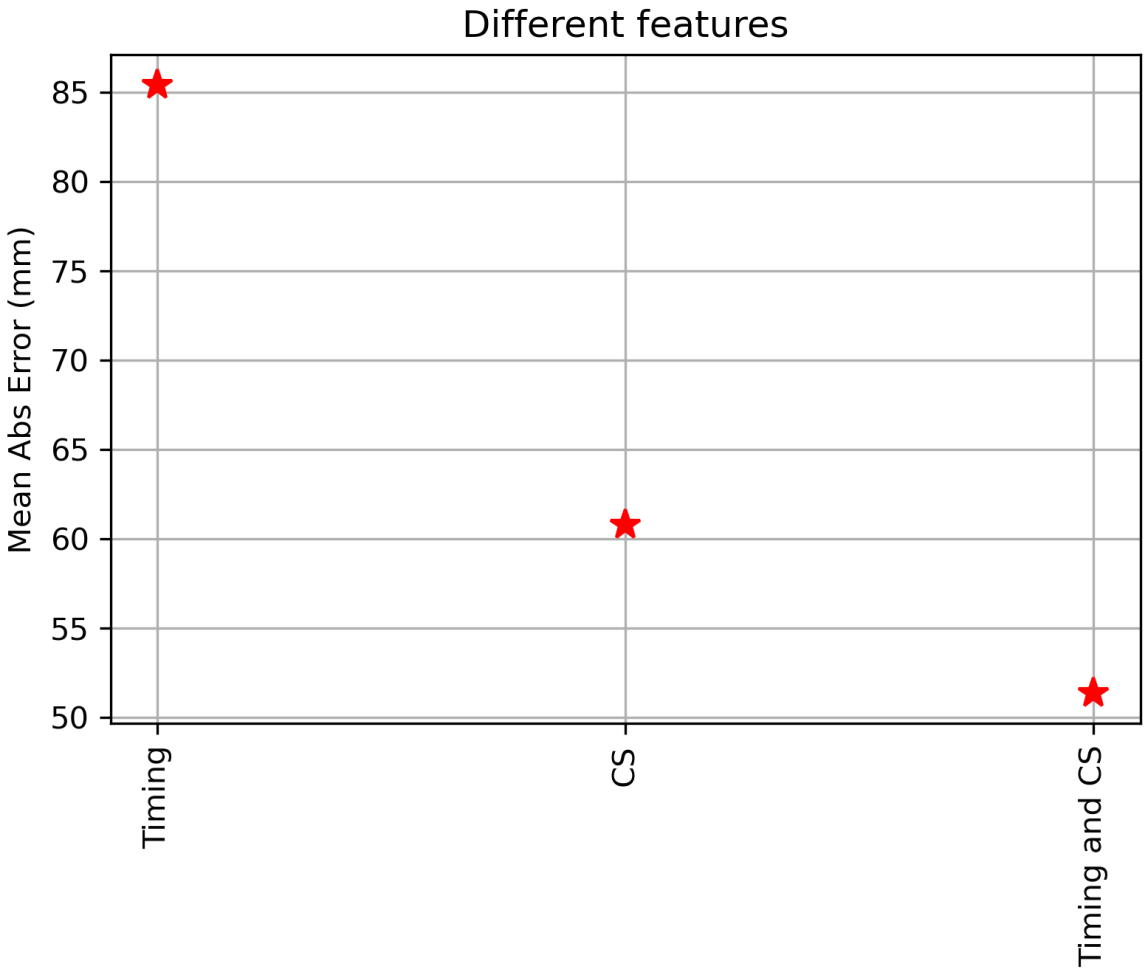
$N_{D_{test}} = test\ data\ set\ size$



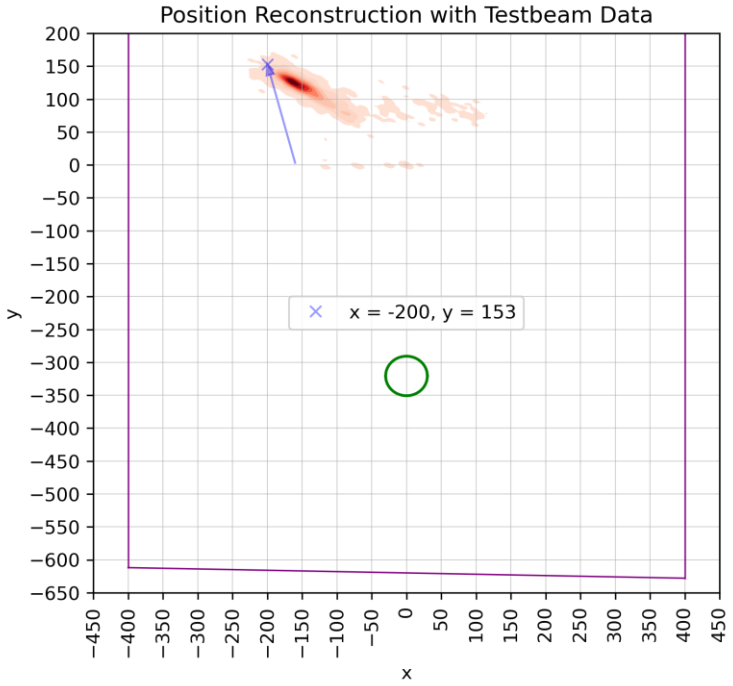
- Keras Api of Tensorflow
- Mean Absolute Error as the Loss function

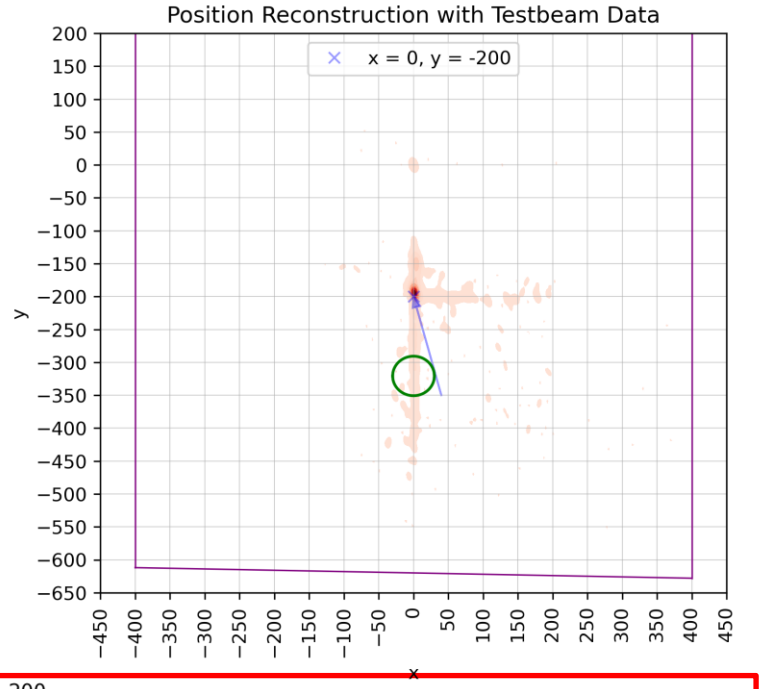
Neural Network: Different Features

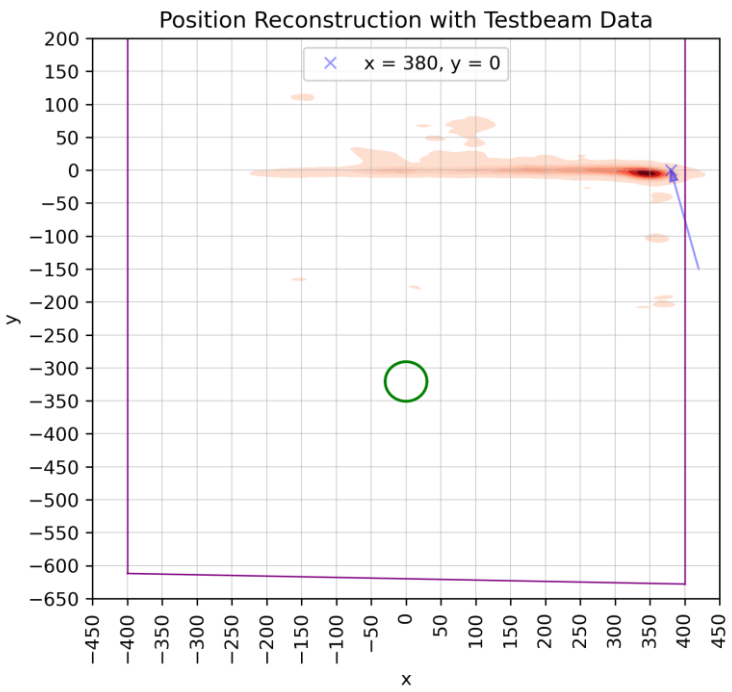
- Timing: 16 features from 16 channels
- CS: 16 charge spectrums from 16 channels
- Timing and CS: (Timing + CS) contains 32 features for input layer
- Best choice: **Timing and CS**

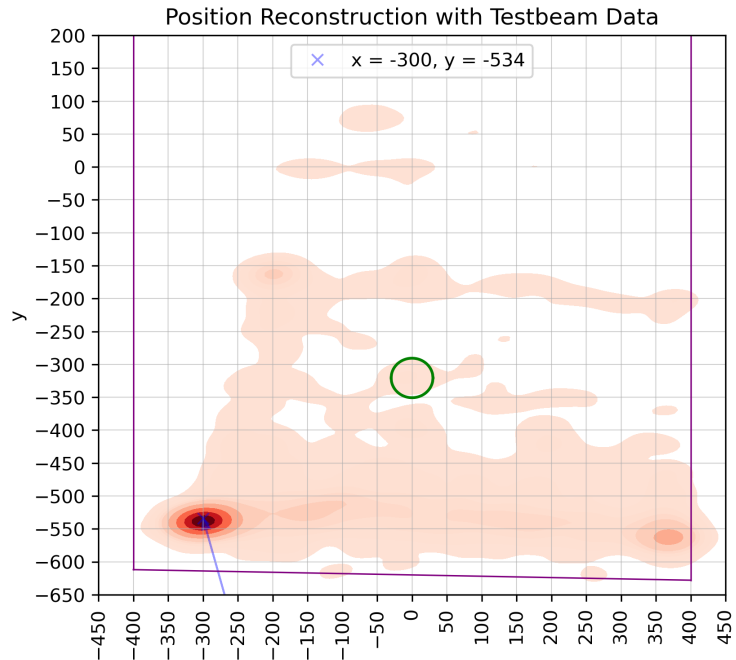


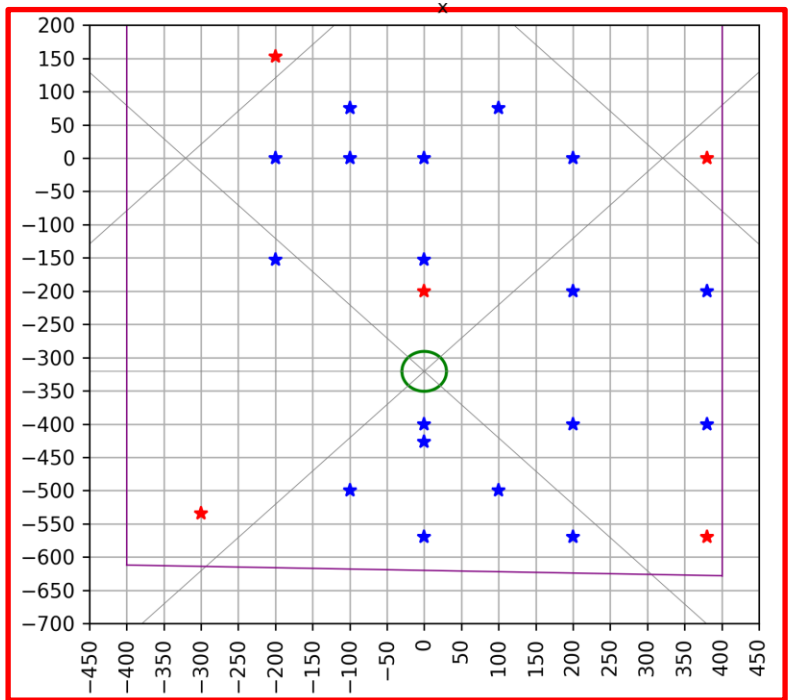
Neural Network: Reconstructions

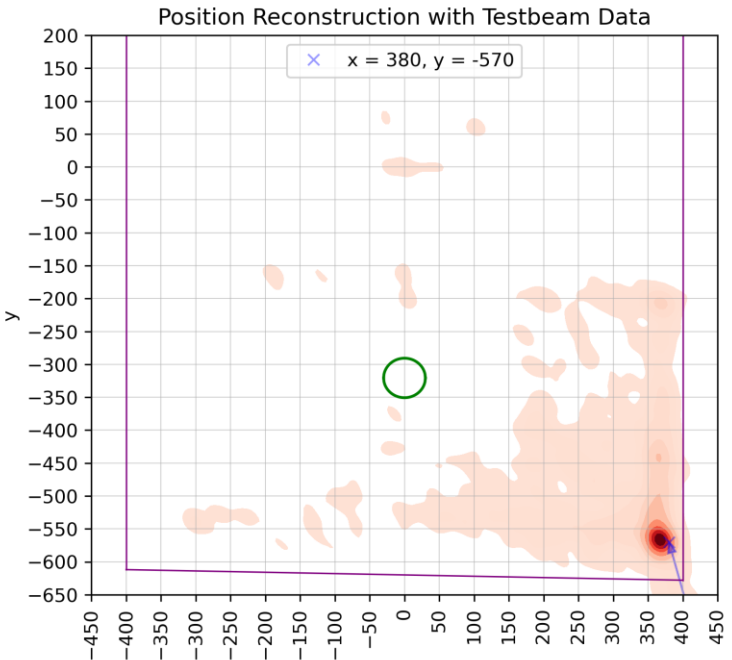








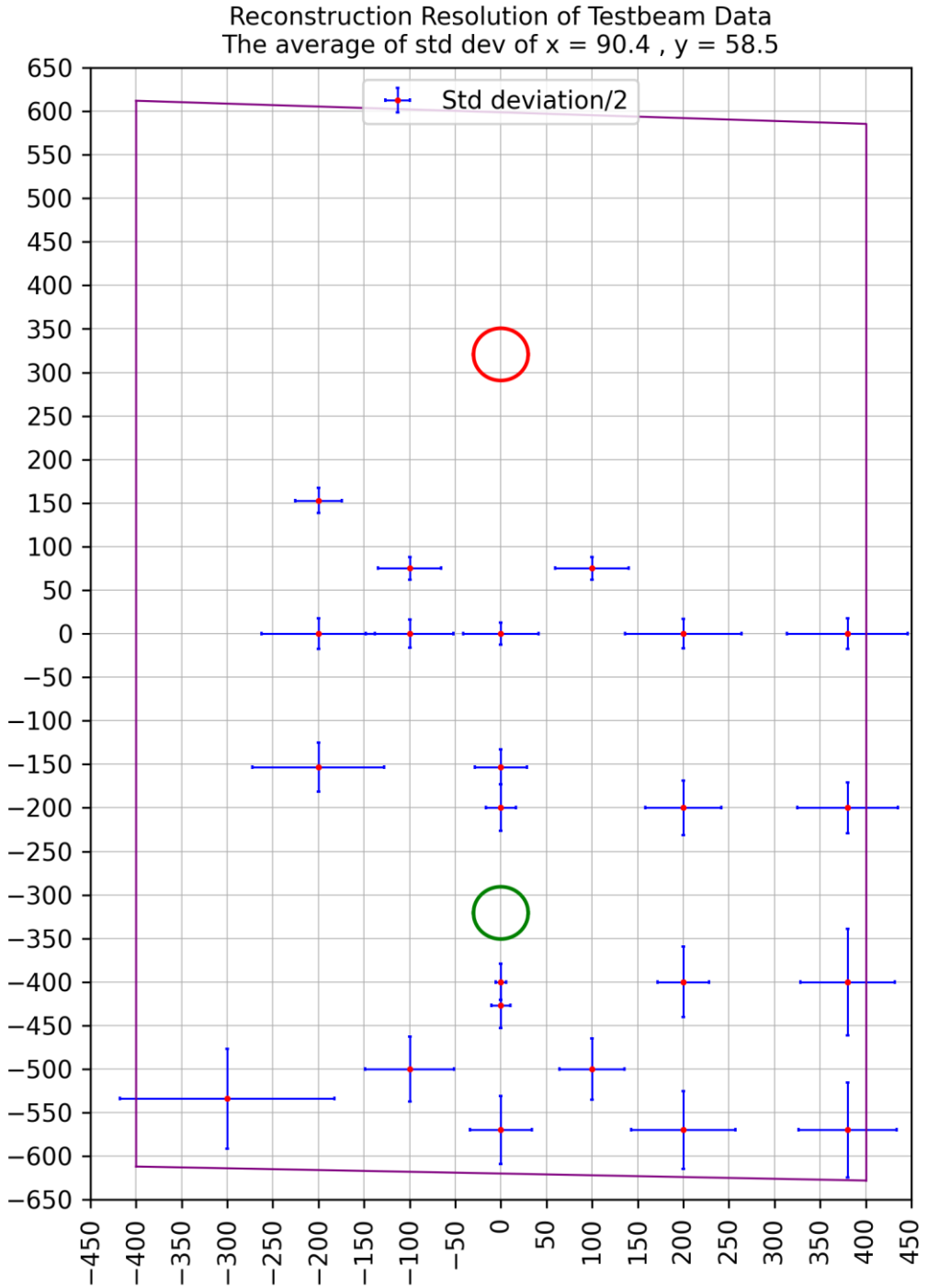




Neural Network: Reconstructions of the Testbeam Data

- Mean σ_x = 90.4 mm
- Mean σ_y = 58.5 mm
- MAE_x = 69.4 mm
- MAE_y = 32.6 mm

- Only D_{test} has been used for evaluating the reconstructions.

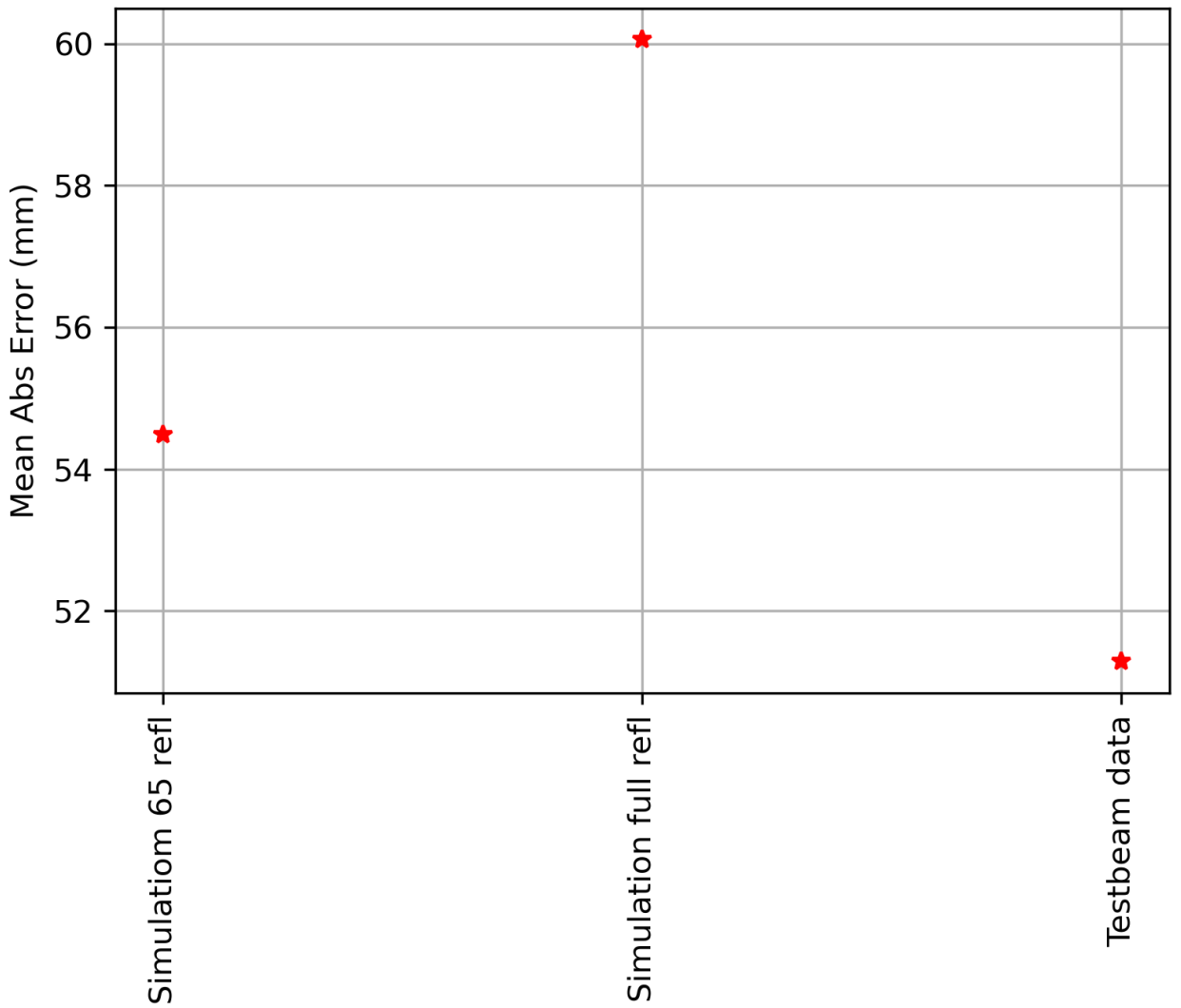


3. Neural Network: MC Simulation

MC Simulation GEANT4

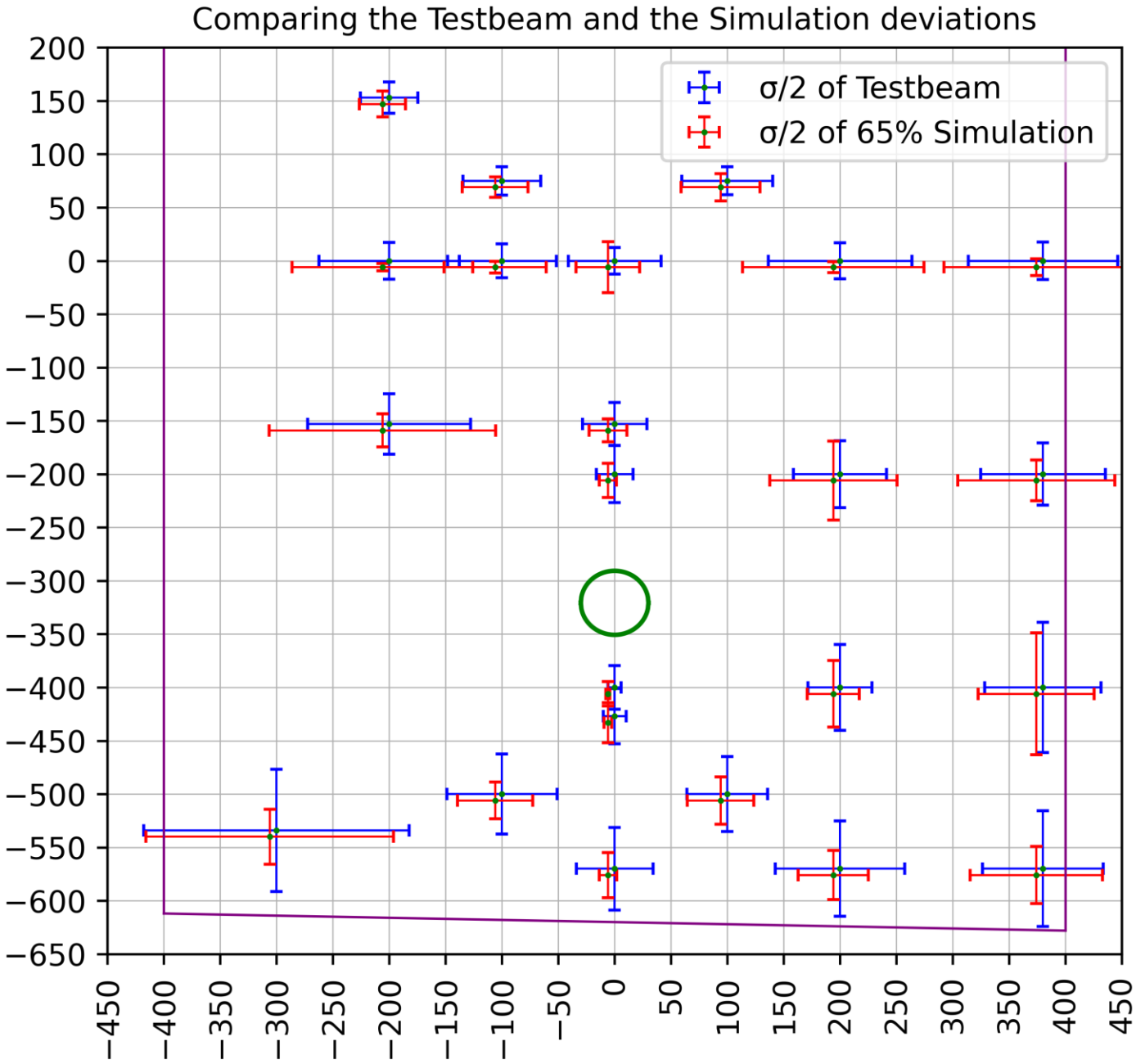
- Same Data set as we have for Testbeam with same beam positions.
- From previous presentation: We should use 65% of the default reflectivity.

- Reconstruction results of MC simulation would be closer to Testbeam if we use 65% reflectivity (same bias)



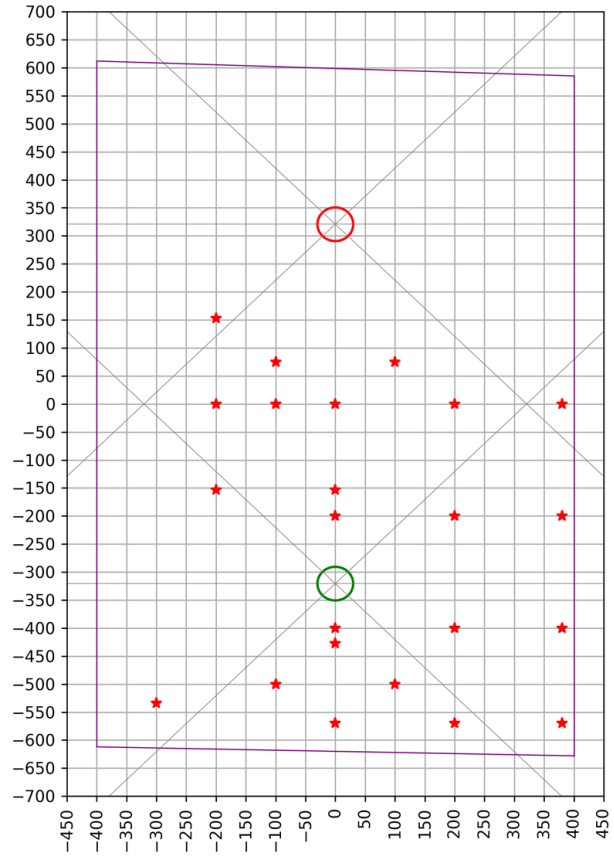
Comparing the Obtained Results of MC and Testbeam

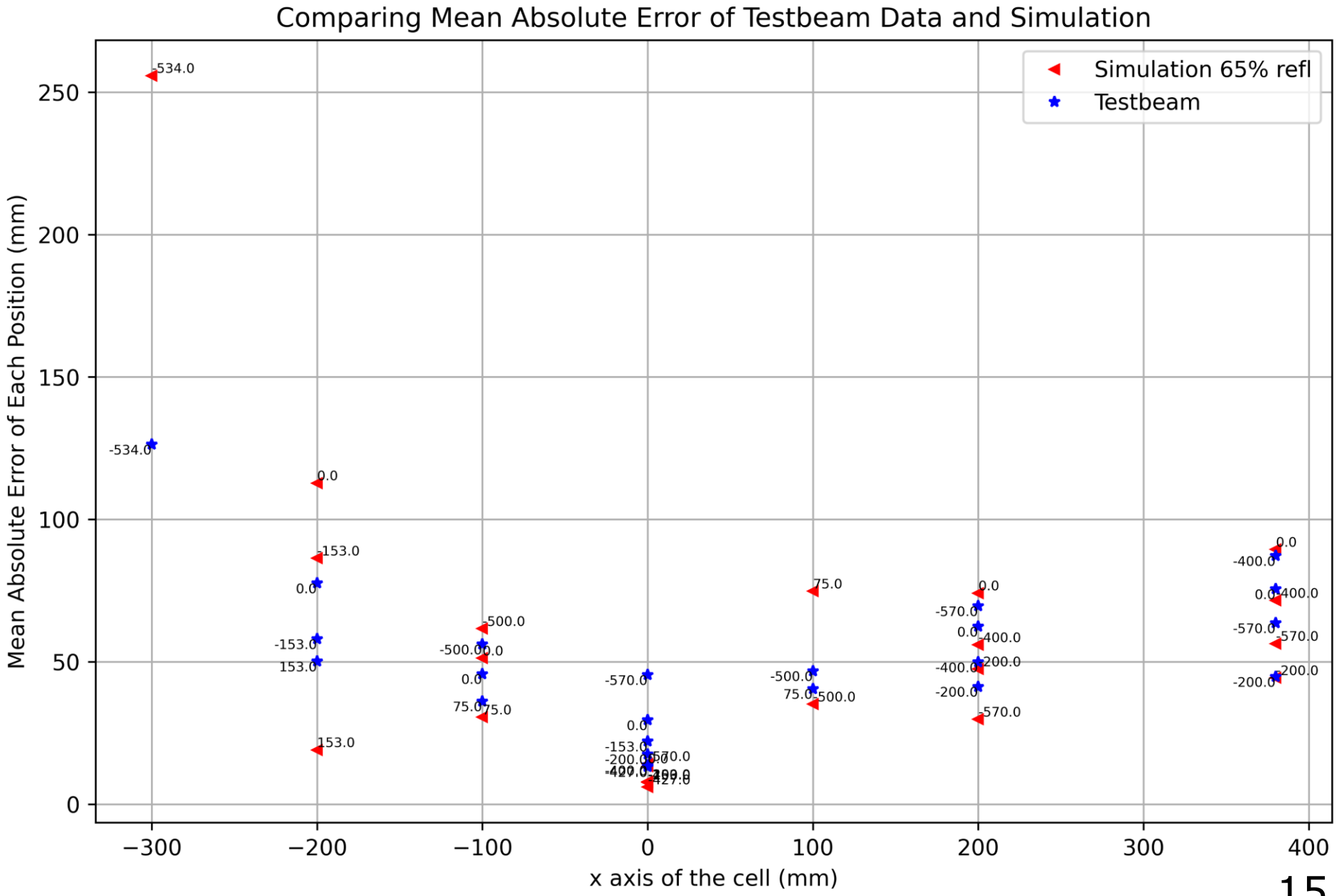
	Testbeam	**Simulation**
MAE_x mm	69.4	**89.3**
MAE_y mm	32.6	**19.7**
σ_x mm	90.4	**87.1**
σ_y mm	58.5	**37.7**



Comparing the Obtained Results

- Annotated numbers referred to y position.





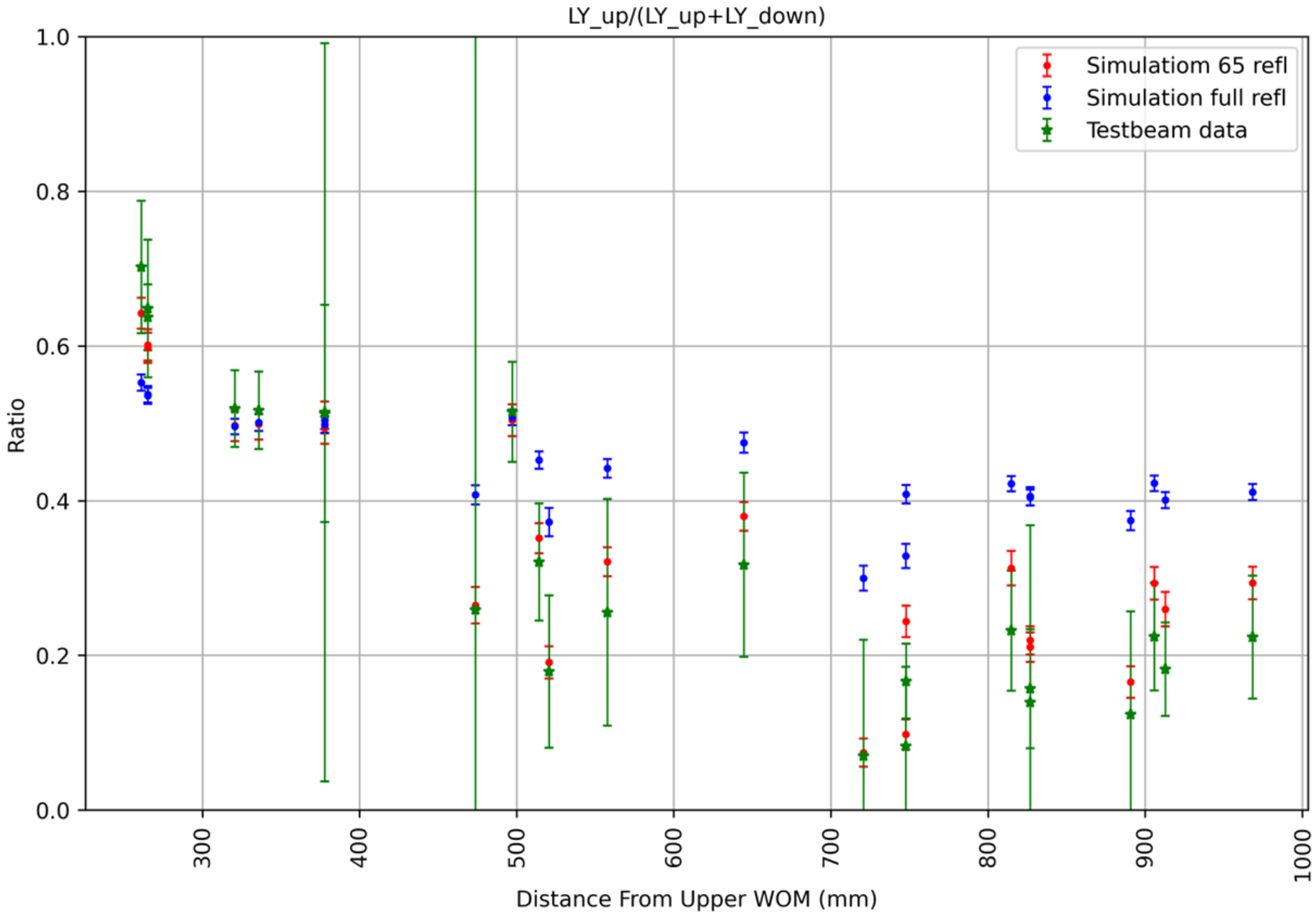
Conclusions

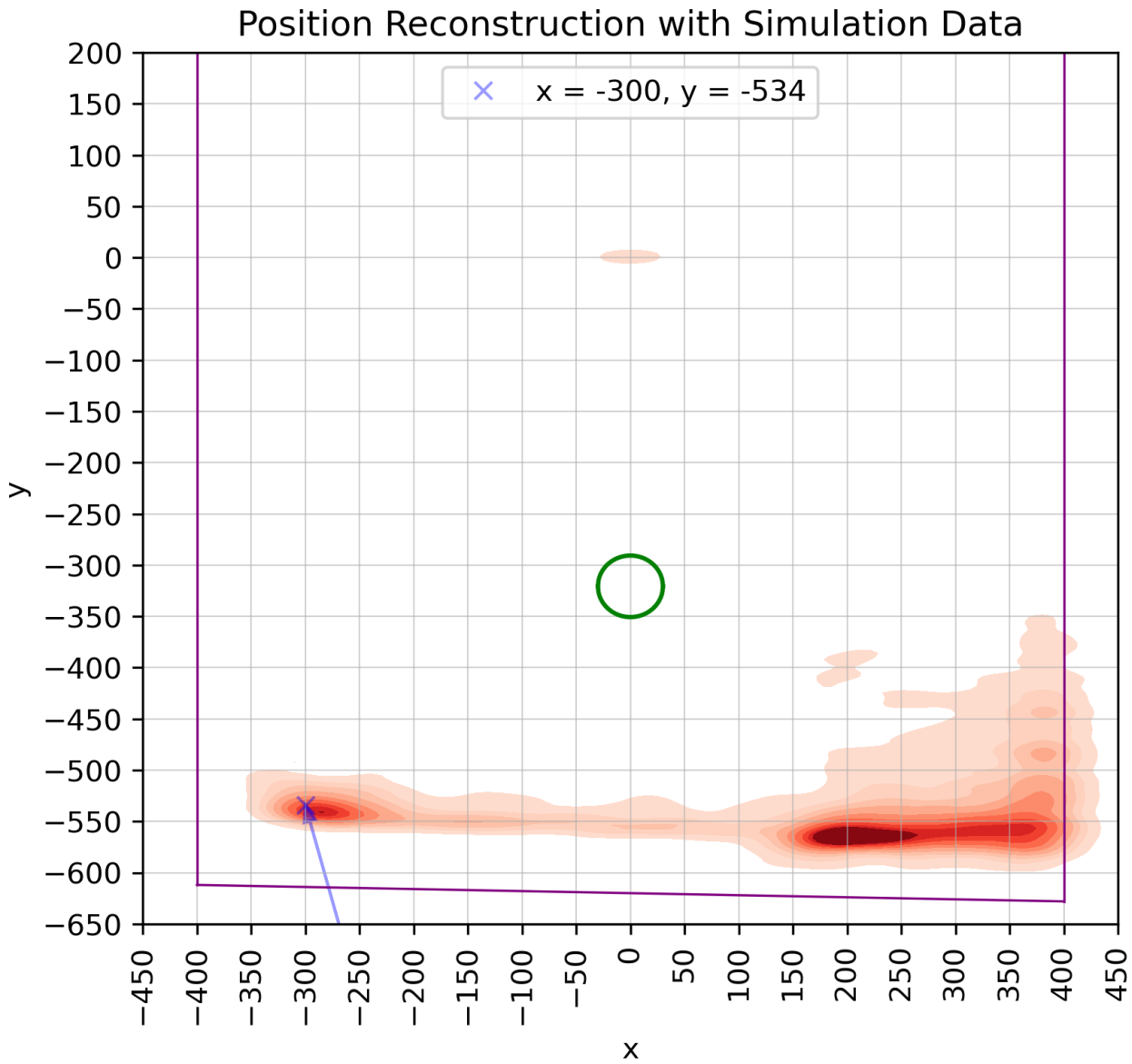
- 1-cell SBT prototype is capable to reconstruct the beam's position at 0 degree with: MAE = 51.0 $_{(mm)}$ σ = 72.4 $_{(mm)}$.
- We get better results if we use both Timing and Charge Spectrum.
- Testbeam data and MC agree better w.r.t spatial particle reconstruction if one uses 65% of the default reflectivity in Simulation.

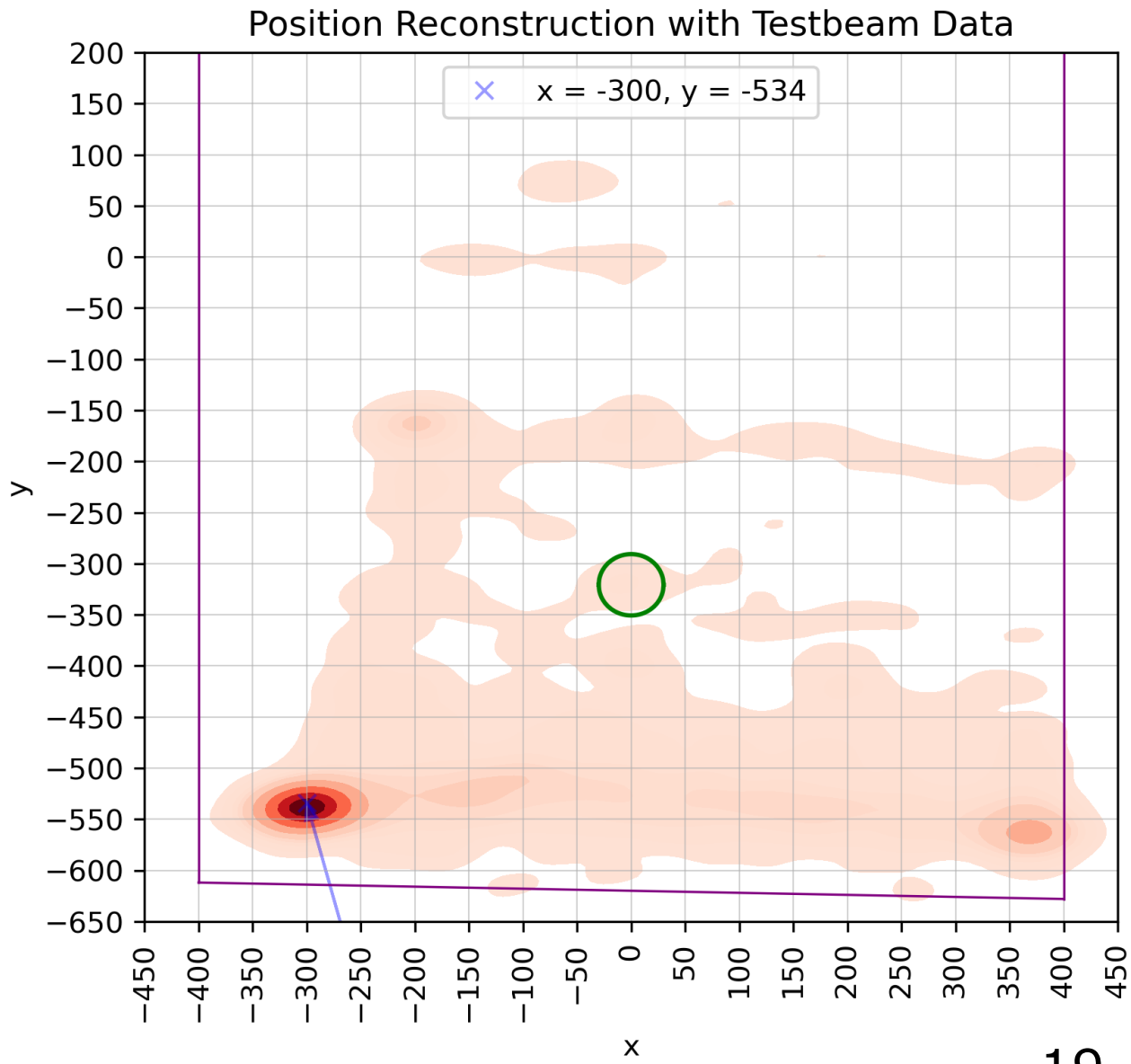
Outlook

- One can possibly reconstruct the energy and the angle of the beam with same method.
- We can train the network with the MC Simulation data all over the cell and test it with the Testbeam data.

Thanks for your attention


LY_up/(LY_up+LY_down)
Simulatiom 65 refl
Simulation full refl
Testbeam data
Ratio
1.0
0.8
0.6
0.4
0.2
0.0
300
400
500
600
700
800
900
1000
Distance From Upper WOM (mm)


Position Reconstruction with Simulation Data
x = -300, y = -534
x
y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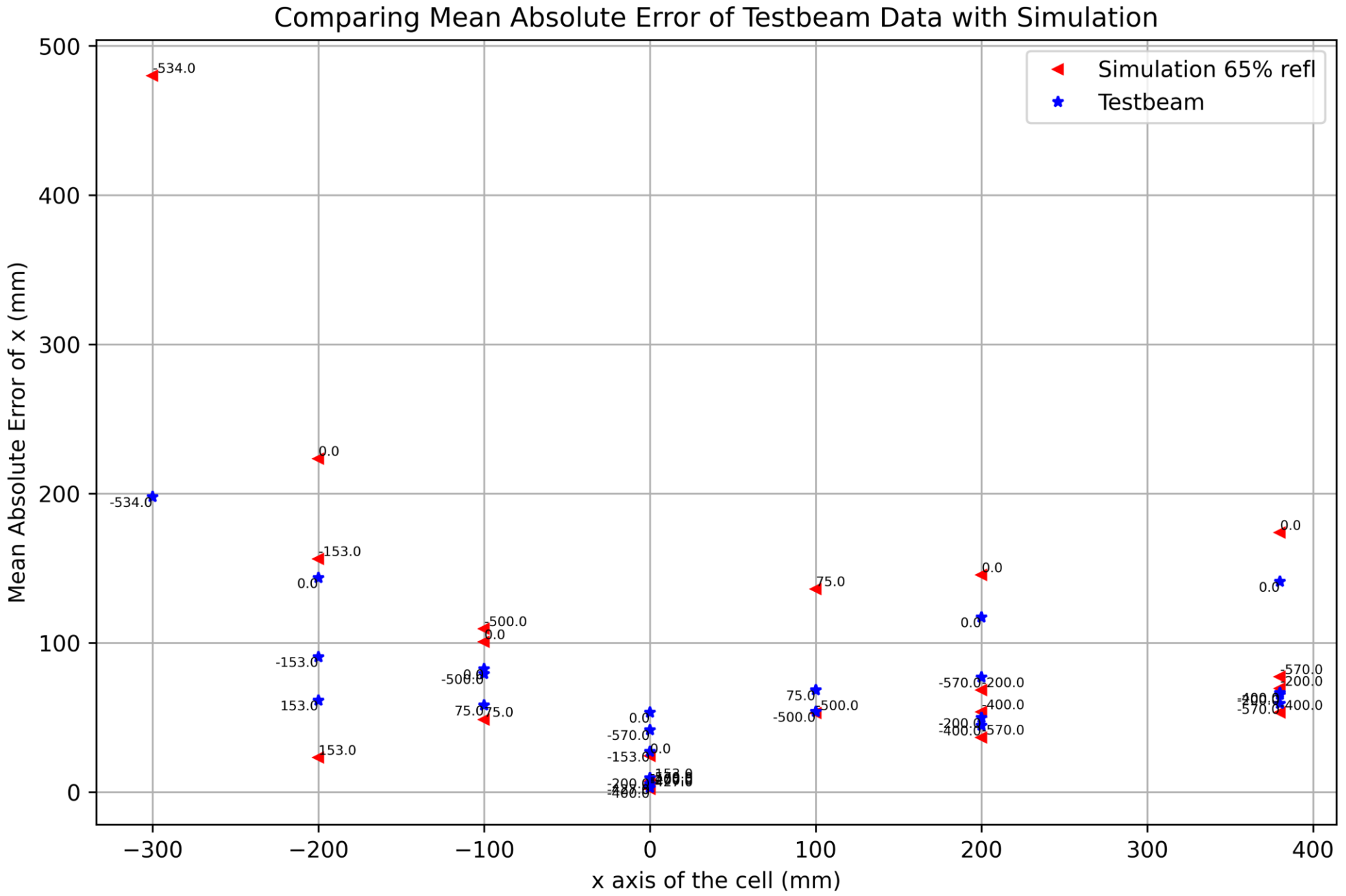
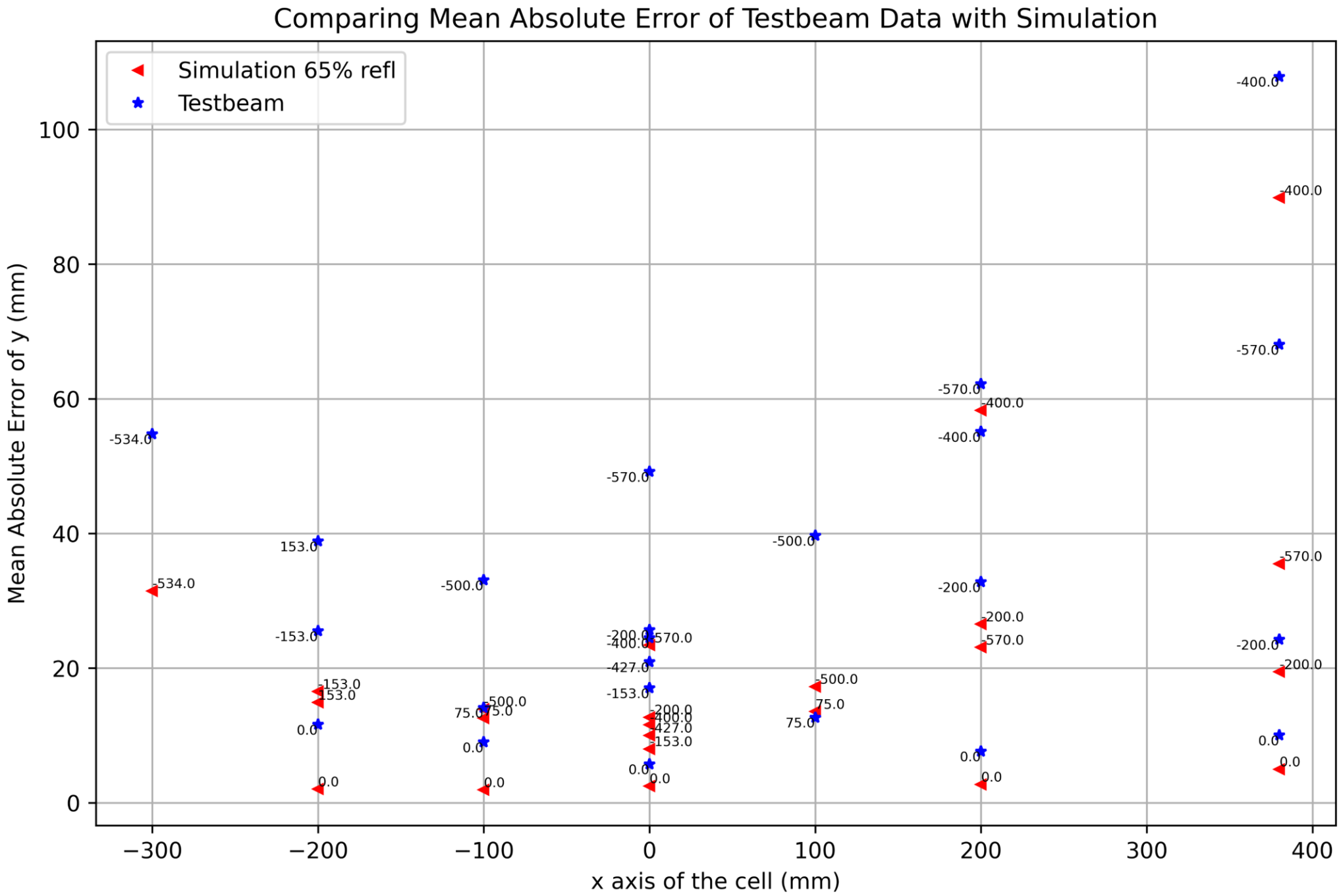
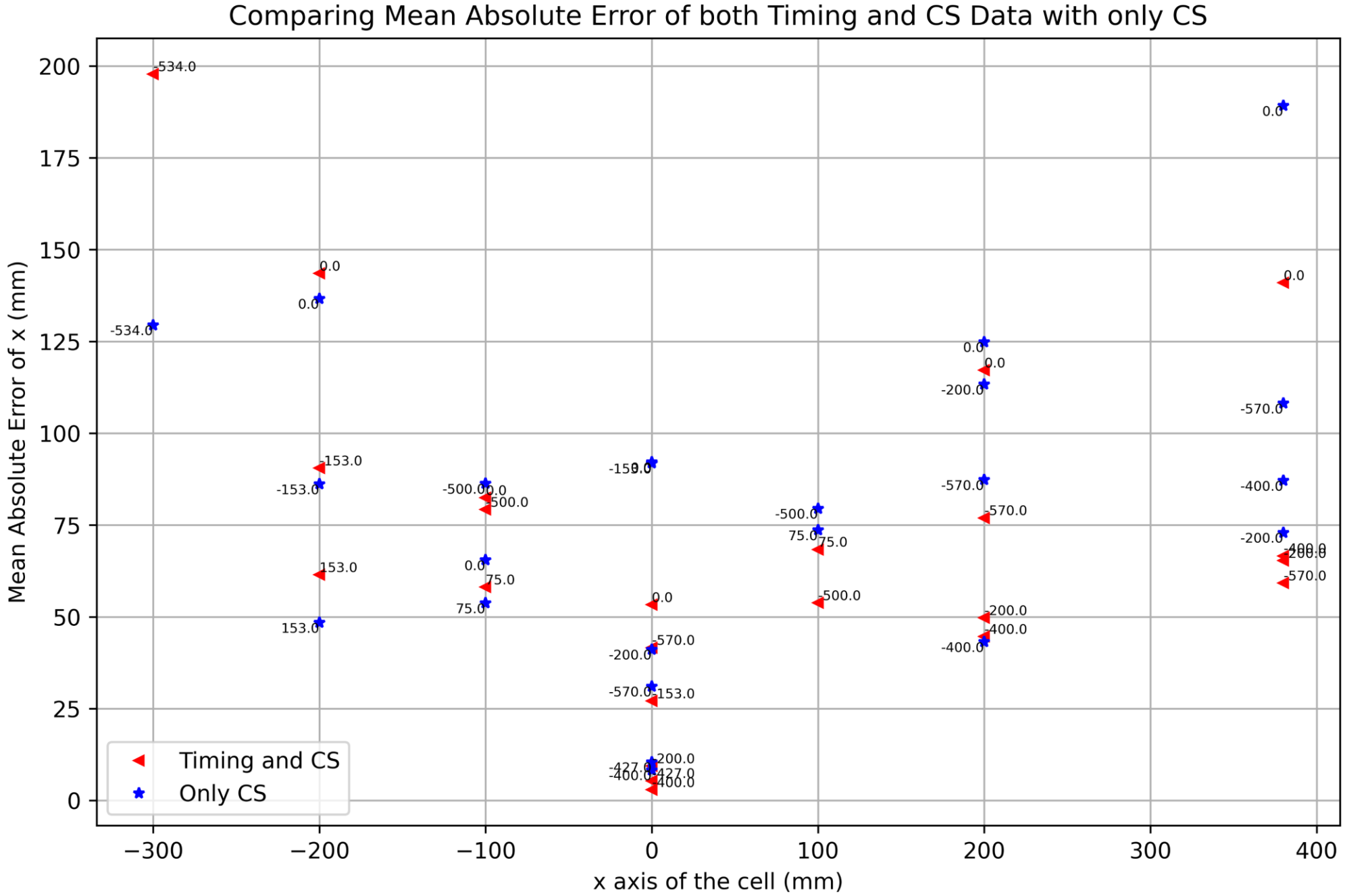
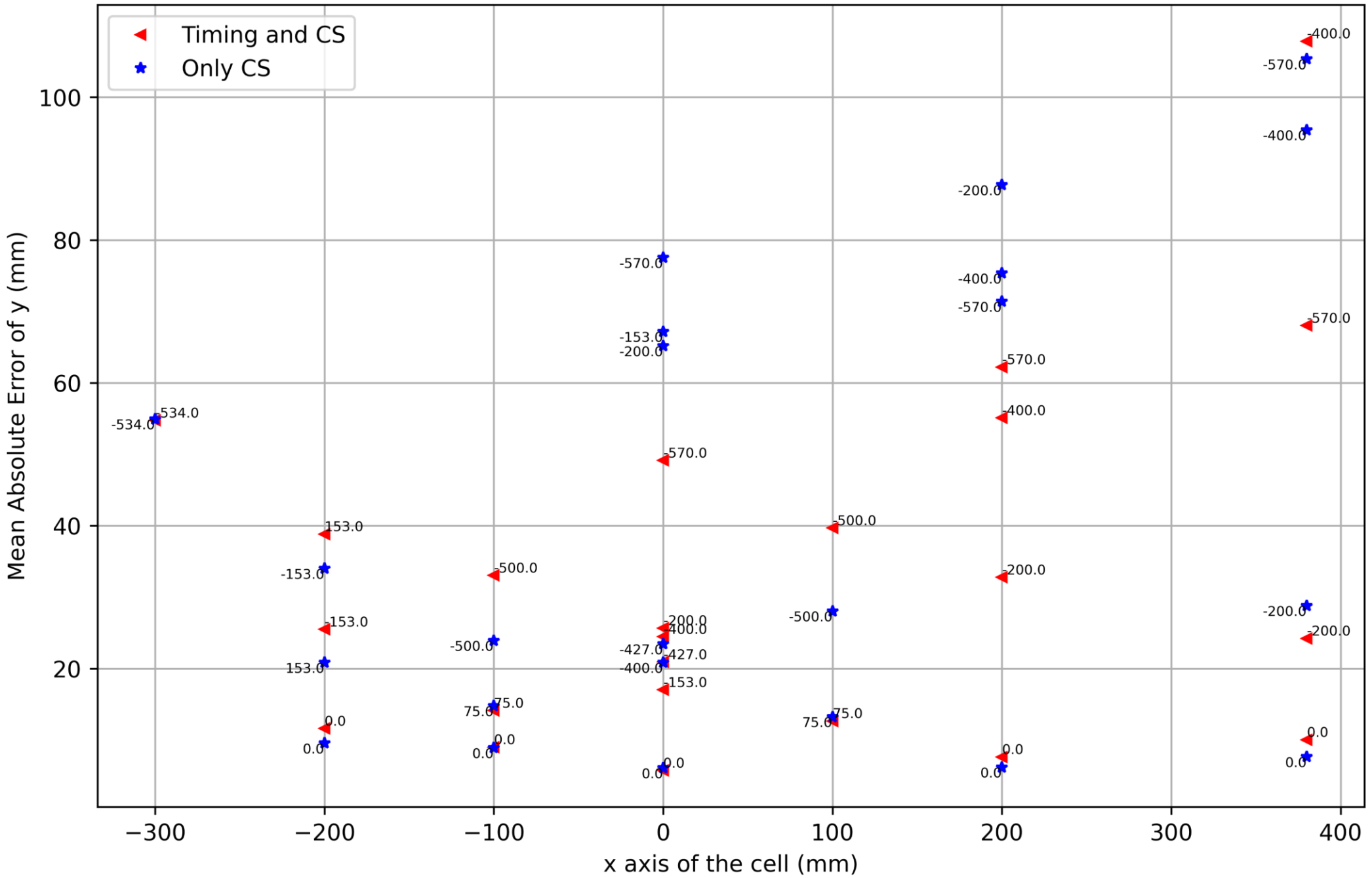
x = -300, y = -534
x
y


Comparing Mean Absolute Error of Testbeam Data with Simulation
Simulation 65% refl
Testbeam
Mean Absolute Error of x (mm)
x axis of the cell (mm)
500
400
300
200
100
0
−300
−200
−100
0
100
200
300
400


Comparing Mean Absolute Error of Testbeam Data with Simulation
Simulation 65% refl
Testbeam
Mean Absolute Error of y (mm)
x axis of the cell (mm)
0
20
40
60
80
100
−300
−200
−100
0
100
200
300
400


Comparing Mean Absolute Error of both Timing and CS Data with only CS
Mean Absolute Error of x (mm)
x axis of the cell (mm)
Timing and CS
Only CS
200
175
150
125
100
75
50
25
0
−300
−200
−100
0
100
200
300
400


Comparing Mean Absolute Error of both Timing and CS Data with only CS
Timing and CS
Only CS
Mean Absolute Error of y (mm)
x axis of the cell (mm)
100
80
60
40
20
−300
−200
−100
0
100
200
300
400