Vernier Analysis Update
Run 12

Mike Beaumier

UC Riverside

May 9, 2016

Outline

From Last Time

From Last Time

From Last Time

Homework:
Progress:
New:

Simulation Progress

Discussion

Conclusion

Conclusion

Backup

Run 359711, Scan Step 7

Figure 1 :

Run 359711, Scan Step 8

Figure 2 :

Run 359711, Scan Step 9

Figure 3 :

Run 359711, Scan Step 10

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 93.192871
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ 0.000051
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.018549
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0.06
Y_OFFSET 0
ZDC_COUNTS 38126
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_10
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0

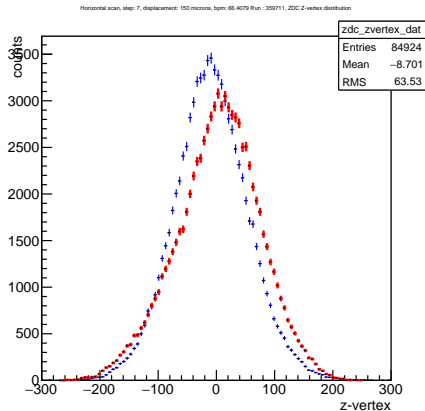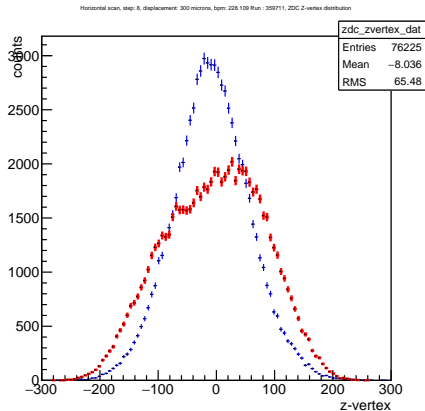Figure 4 :

Run 359711, Scan Step 11


```
AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 92.063965
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ 0.000065
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.012652
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0.075
Y_OFFSET 0
ZDC_COUNTS 25266
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_11
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0
```
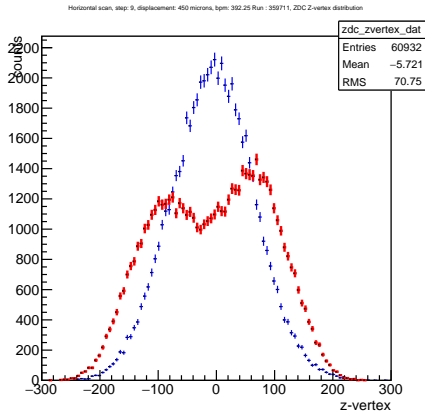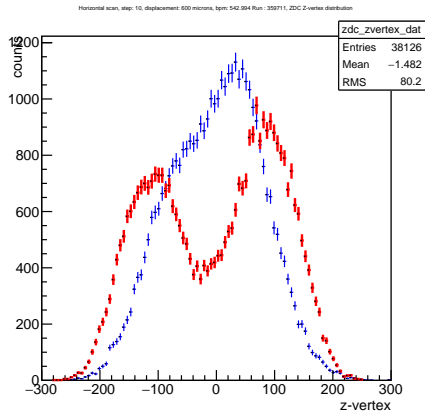
Figure 5 :

Run 359711, Scan Step 12

Figure 6 :

Run 359711, Scan Step 13

Figure 7 :

Run 359711, Scan Step 14

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 80.077638
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ -0.000078
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.007320
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0
Y_OFFSET -0.075
ZDC_COUNTS 4116
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_14
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0

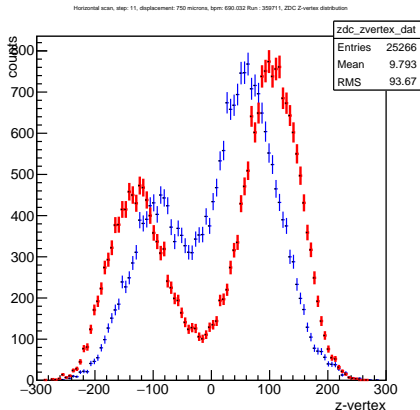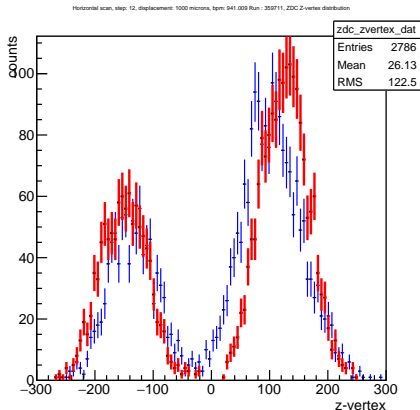Figure 8 :

Run 359711, Scan Step 15

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 83.563965
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ -0.000078
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.033369
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0
Y_OFFSET -0.06
ZDC_COUNTS 11658
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_15
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0

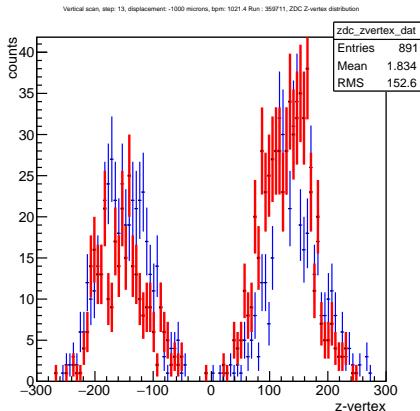Figure 9 :

Run 359711, Scan Step 16


```
AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 92.080567
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ -0.000078
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.136202
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0
Y_OFFSET -0.045
ZDC_COUNTS 28561
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_16
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0
```
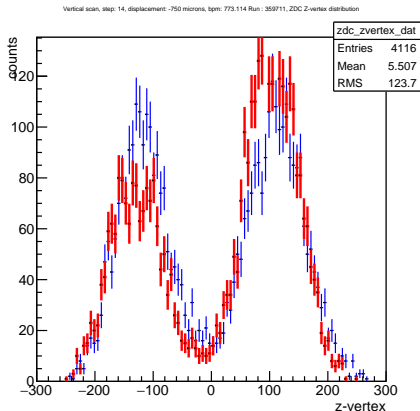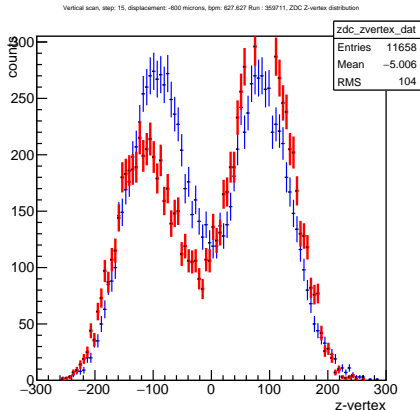
Figure 10 :

Run 359711, Scan Step 17

Figure 11 :

Run 359711, Scan Step 18

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 92.196777
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ -0.000078
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.437010
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0
Y_OFFSET -0.015
ZDC_COUNTS 74684
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_18
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0

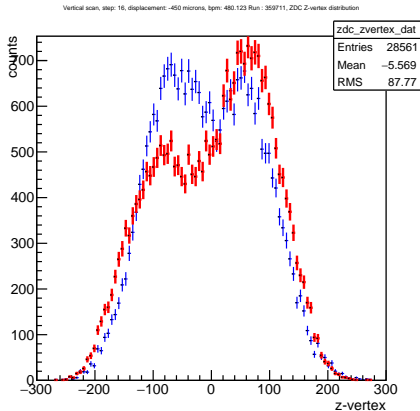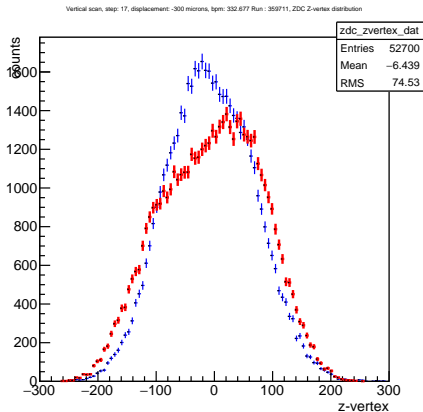Figure 12 :

Run 359711, Scan Step 19

Figure 13 :

Run 359711, Scan Step 20

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85.390138
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ 0.000002
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.223648
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET 0
Y_OFFSET 0.015
ZDC_COUNTS 77749
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_20
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
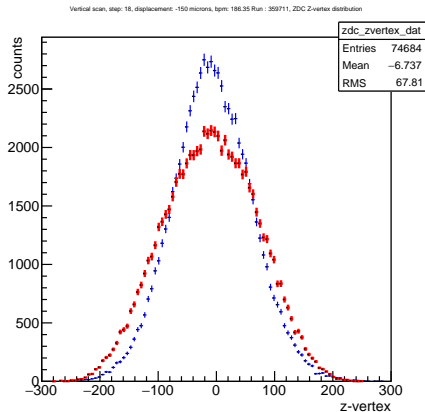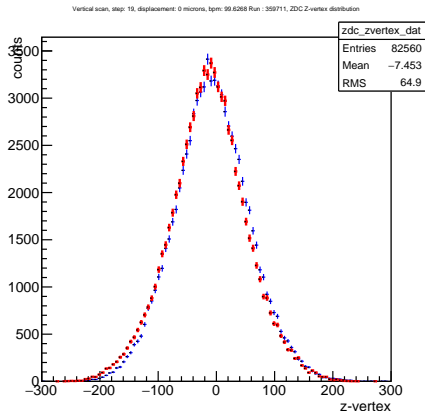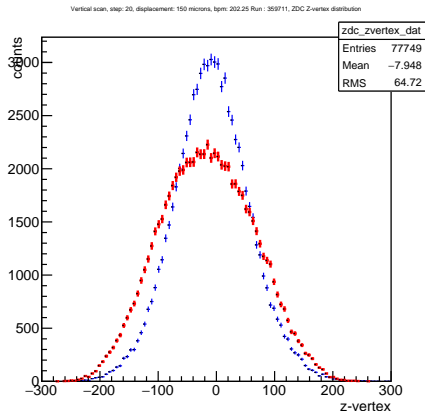Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0

Figure 14 :

Run 359711, Scan Step 21

Figure 15 :

Run 359711, Scan Step 22

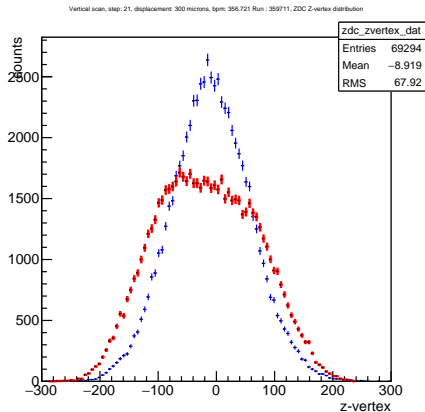| AVG_NUMBER_IONS_BLUE_BEAM 120.029e9 |
| AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9 |
| BBC_ZDC_Z_VERTEX_OFFSET -9.53756 |
| BETA_STAR 88.693848 |
| BUNCH_CROSSING_FREQUENCY 78213. |
| CROSSING_ANGLE_XZ 0.000002 |
| CROSSING_ANGLE_YZ 0. |
| FILLED_BUNCHES 107 |
| HORIZONTAL_BEAM_WIDTH 0.0245674 |
| MAX_COLLISIONS 5 |
| MULTIPLE_COLLISION_RATE 0.101992 |
| RUN_NUMBER 359711 |
| VERTICAL_BEAM_WIDTH 0.0238342 |
| X_OFFSET 0 |
| Y_OFFSET 0.045 |
| ZDC_COUNTS 46910 |
| ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_22 |
| Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95 |
| Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15 |
| Z_BUNCH_WIDTH_LEFT_OFFSET -70.2 |
| Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65 |
| Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7 |
| Z_PROFILE_SCALE_VALUE 2.0 |

Figure 16 :

Run 359711, Scan Step 23

Figure 17 :

Run 359711, Scan Step 24

Figure 18 :

Run 359711, Scan Step 25
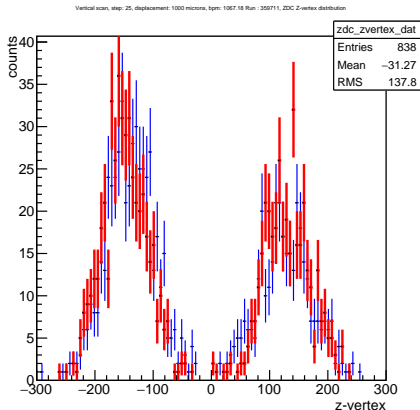
Figure 19 :

From Last Time

- Explored various parameteterizations of the beam z-profile
- Fits show same results as data driven method, but they are wrong
- Simple gaussian model produces different results when used in Amaresh's framework vs my framework
- Machinery in place for rootfinding, minimization of differences between simulation and data.

From Last Time

Homework:
I was tasked to figure out why the simple gaussian model looks wrong - there should be a symmetric ZDC z-profile gaussian, centered at $z = 0$, if model is implimented correctly.

Progress:
I found the problem in the code - the difference between my method, and Amaresh's method was how we handled normalization. As we know, gaussians have normalization dependant on the width of the distriubtion, but this width gains additional z-dependance when considering the β^* squeeze effect. I implimented this, and now distributions match very closely.

New: Last time, I mentioned that multiple-collisions do not effect the resultant distributions. I was wrong - so this parameter has been added back into the simulation.

Parameter Space

- Since I have not done the multiple collisions correction myself, I use the Run 15 numbers, and create a graph of scan-step vs multiple collisions rate, from which I interpolate the rate. To account for luminosity shifts, I allow the parameter to vary by a factor of 50%.

- Care should be taken, as Run 15 had a higher average luminosity by a factor of 2, with respect to Run 12.

- Because distributions are generated randomly, there is some fluctuation in the final spectra. Therefore, we not halt the simualtion after 10 iterations, Which corresponds to the binary search step reaching a size of less than 1% of the value of the original seed parameter.

Discussion

Simulations are in good agreement with data for available scanning steps, with the following caveats:

- **Caveat:** The vernier scan can be broken down into four half-scans - portions where the beam starts maximally displaced, and ends maxmially overlapped (or the reverse).
- **Caveat:** We therefore can configure the simulation to handle one half-scan, but then require that we transpose this code properly to each other half scan.
- **Caveat:** Currently, we have simulated the first half of the horizontal scan.
- **Caveat:** Other scans were simulated also, but the results should not be trusted, because further adjustments are needed.
- **Caveat:** Therefore, the first half scan, horizontal scans for Run 359711 have been simulated, along with the other three, but bugs present in the transposition are affecting the profiles for steps 7-25.
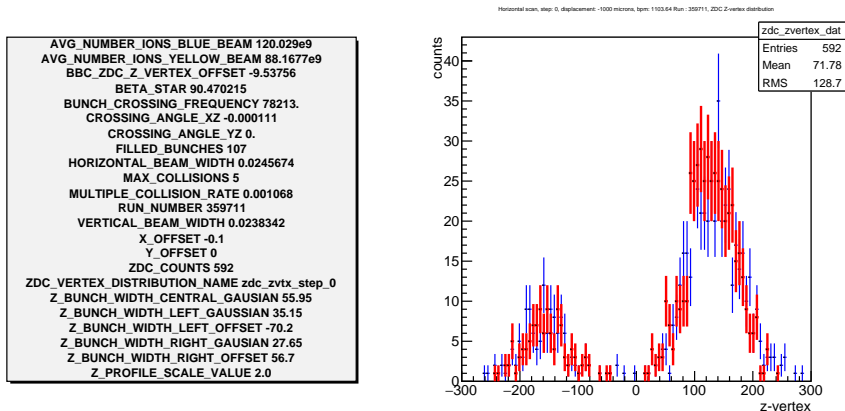
Run 359711, Scan Step 0


```
AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 90.470215
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.000111
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001068
RUN_NUMBER 359711
VERTICAL_BEAM_WIDTH 0.0238342
X_OFFSET -0.1
Y_OFFSET 0
ZDC_COUNTS 592
ZDC_VERTEX_DISTRIBUTION_NAME zdc_zvtx_step_0
Z_BUNCH_WIDTH_CENTRAL_GAUSIAN 55.95
Z_BUNCH_WIDTH_LEFT_GAUSSIAN 35.15
Z_BUNCH_WIDTH_LEFT_OFFSET -70.2
Z_BUNCH_WIDTH_RIGHT_GAUSIAN 27.65
Z_BUNCH_WIDTH_RIGHT_OFFSET 56.7
Z_PROFILE_SCALE_VALUE 2.0
```

Figure 20 :   Excellent matching between simulation and data, watch θ_{xz} - it does not change much.
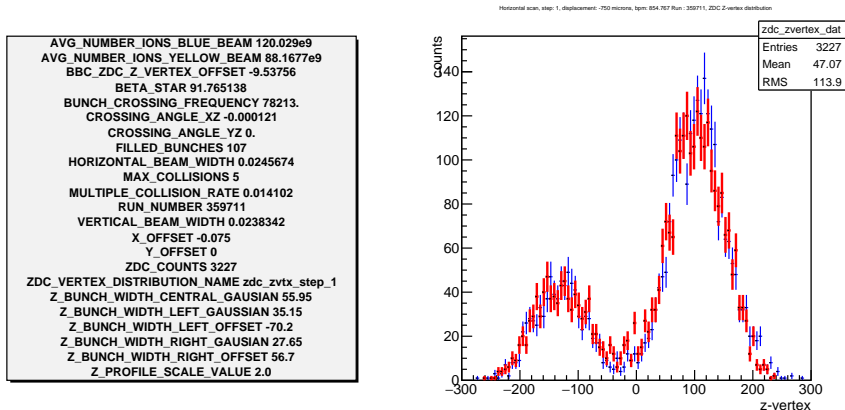
Run 359711, Scan Step 1

Figure 21 : Excellent matching between simulation and data, watch θ_{XZ} - it does not change much.
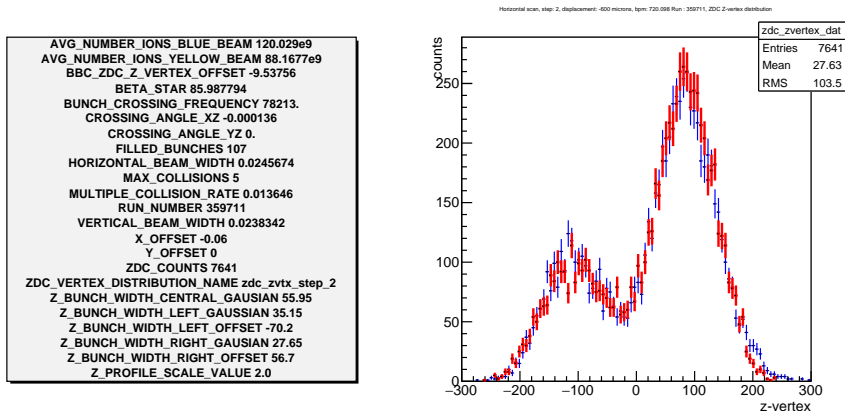
Run 359711, Scan Step 2

Figure 22 : Excellent matching between simulation and data, watch θ_{XZ} - it does not change much.

Run 359711, Scan Step 3
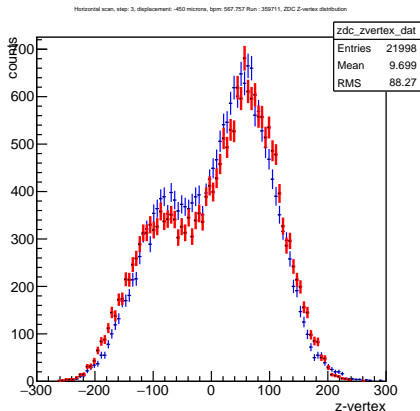

Figure 23 : Excellent matching between simulation and data, watch θ_{XZ} - it does not change much.

Run 359711, Scan Step 4

Figure 24 : Less stable of the "good" distributions. Due to the obvious differences between simlation and data. Note that with the different shape, the β^* and θ_{XZ} do not match the other distributions as well.
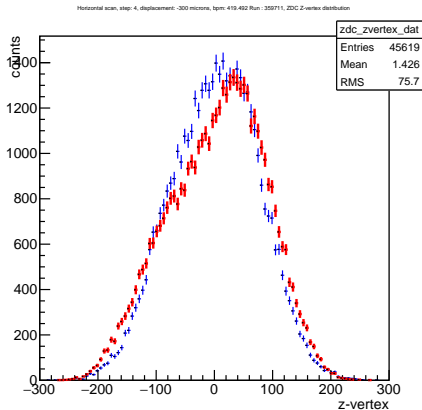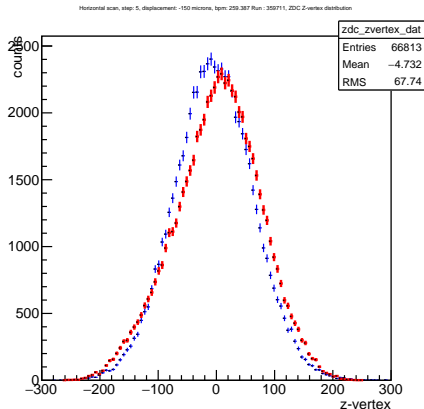
Run 359711, Scan Step 5

Figure 25 : Less stable of the "good" distributions. Due to the obvious differences between simlation and data. Note that with the different shape, the β^* and θ_{XZ} do not match the other distributions as well.

Run 359711, Scan Step 6

Figure 26 :   Note that we see the crossing angle change sign here.

Summary Data

Step	β^*	θ_{XZ}	θ_{YZ}	N_{MC}
0	90.470215	-0.000111	0.	0.001068
1	91.765138	-0.000121	0.	0.014102
2	85.987794	-0.000136	0.	0.013646
3	92.263185	-0.000115	0.	0.096849
4	88.610840	-0.000150	0.	0.255986
5	92.296388	-0.000277	0.	0.249448
6	78.799316	0.000456	0.	0.255518
7	87.830567	0.000330	0.	0.517198
8	93.226075	0.000085	0.	0.320010
9	90.536622	0.000046	0.	0.109506
10	93.192871	0.000051	0.	0.018549
11	92.063965	0.000065	0.	0.012652
12	79.496583	0.000070	0.	0.000809
13	83.563965	-0.08e-3	-0.000078	0.000953
14	80.077638	-0.08e-3	-0.000078	0.007320
15	83.563965	-0.08e-3	-0.000078	0.033369
16	92.080567	-0.08e-3	-0.000078	0.136202
17	92.130371	-0.08e-3	-0.000078	0.114620
18	92.196777	-0.08e-3	-0.000078	0.437010
19	88.395019	0.000437	0.	0.621702
20	85.390138	0.000002	0.	0.223648
21	92.761231	0.000002	0.	0.207431
22	88.693848	0.000002	0.	0.101992
23	92.379395	0.000002	0.	0.028989
24	79.015138	0.000002	0.	0.016319
25	83.613769	0.000002	0.	0.000809

- **Ready:**
  - ▶ **Horizontal Scan Part 1:** Steps 0 through 6 are working properly
- **Needs More Work:**
  - ▶ **Horizontal Scan Part 2:** Steps 6 - 12
  - ▶ **Vertical Scan Part 1:** Steps 13 - 19
  - ▶ **Vertical Scan Part 2:** Steps 20 - 25
- Probably a small bug in the code resulting from imporper translation between scans.