Vernier Analysis Update

Run 12

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Outline

Z Bunch Profile Studies

The Z Bunch Profile

Last time we discussed directly using the z-bunch profile in the hourglass simulation. Here I discuss preliminary methods and results

The Z Bunch Profile

- Recall that our model of luminosity depends on the convelution of two normal, three dimensional distriubtions moving through each-other:

$$\mathcal{L} \propto \int\int\int\int_{\infty}^{\infty} \rho_{blue}(x, y, z - ct_0)\rho_{yellow}(x, y, z + ct_0)dxdydzdt \quad (1)$$

- And that we may do simple substitutions for coordinates to represent rotations and β^* squeezing.
- We need a means to use a distriubtion of points similarly to a function, so that we may achieve a mapping of inputs (or transformed inputs) to outputs.

The Z Bunch Profile

We start with the fine-binned profile:

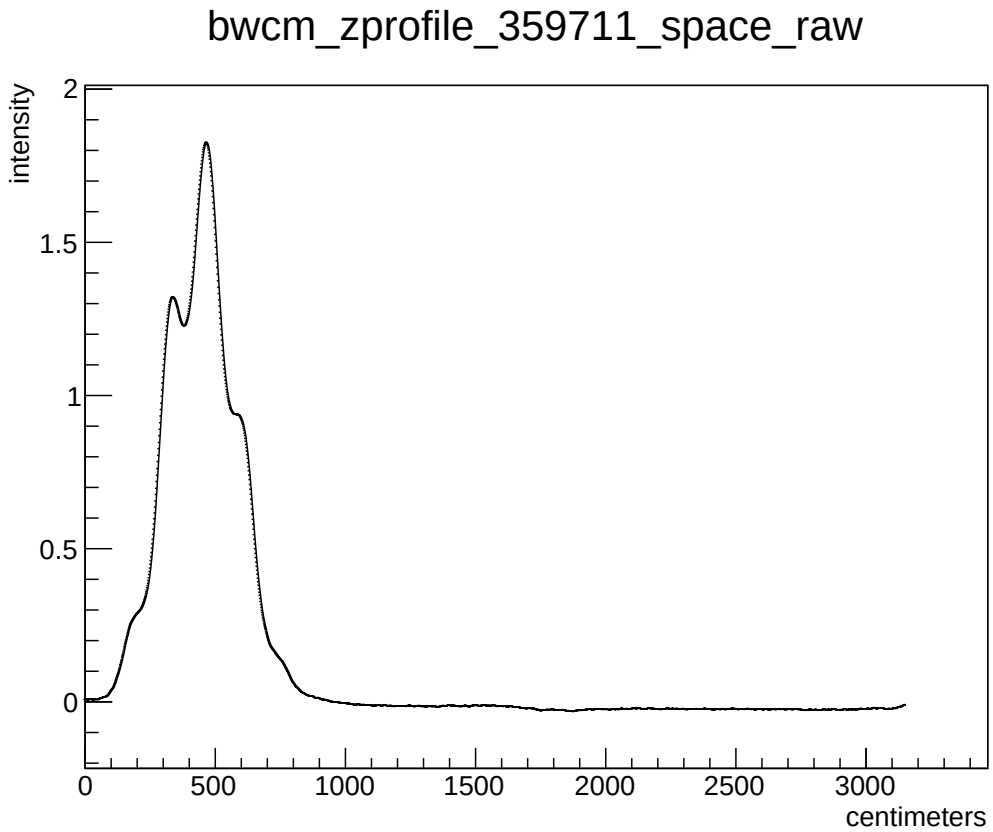

Figure 1 : Full bunch profile over time period of approximately 106 ns

The Z Bunch Profile

Shift the profile:

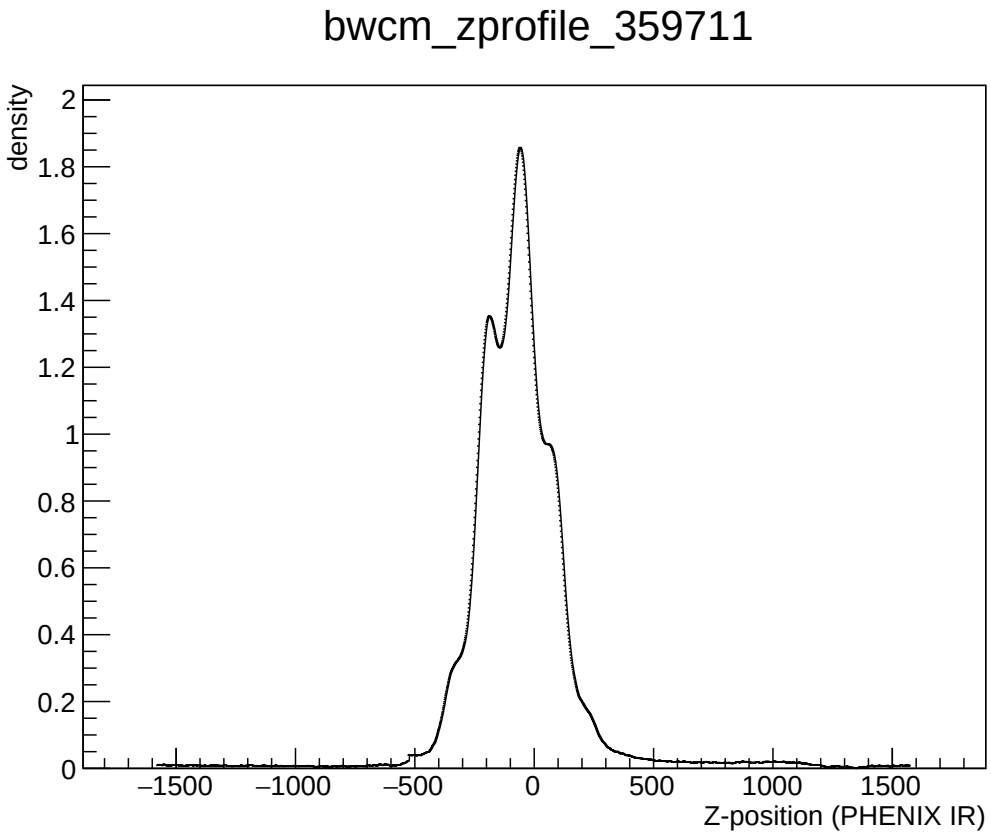

Figure 2 : Full bunch profile over time period of approximately 106 ns, shifted

The Z Bunch Profile

And normalize:

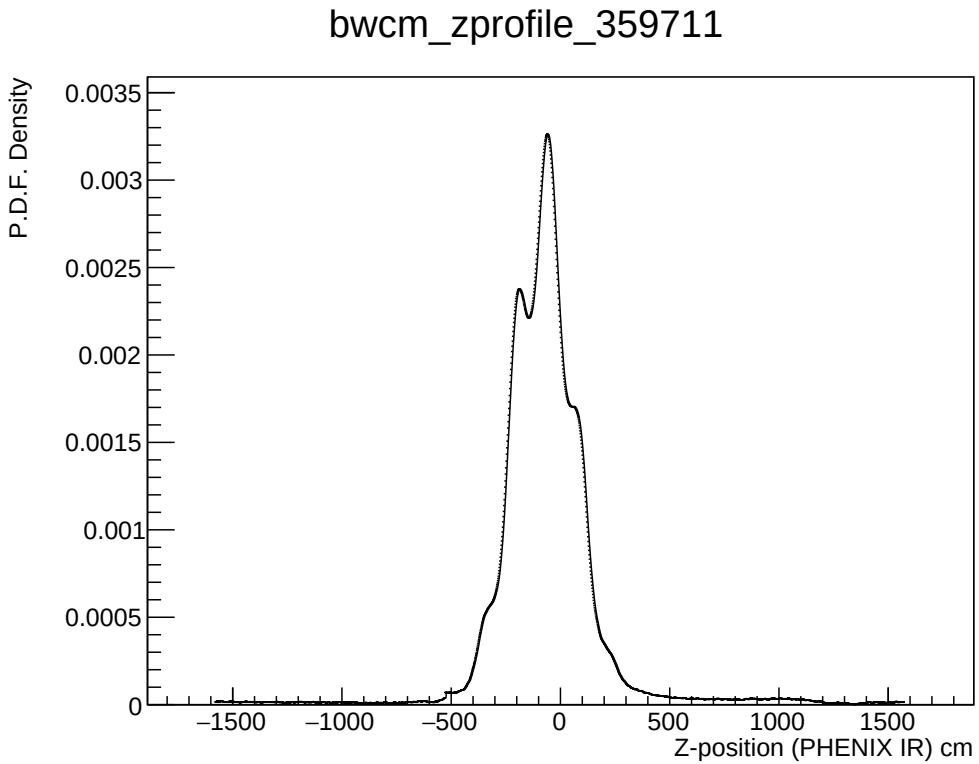

Figure 3 : Full bunch profile over time period of approximately 106 ns, shifted, normalized

Z Bunch Profile - Inidivdual Bunches, Fill 16444

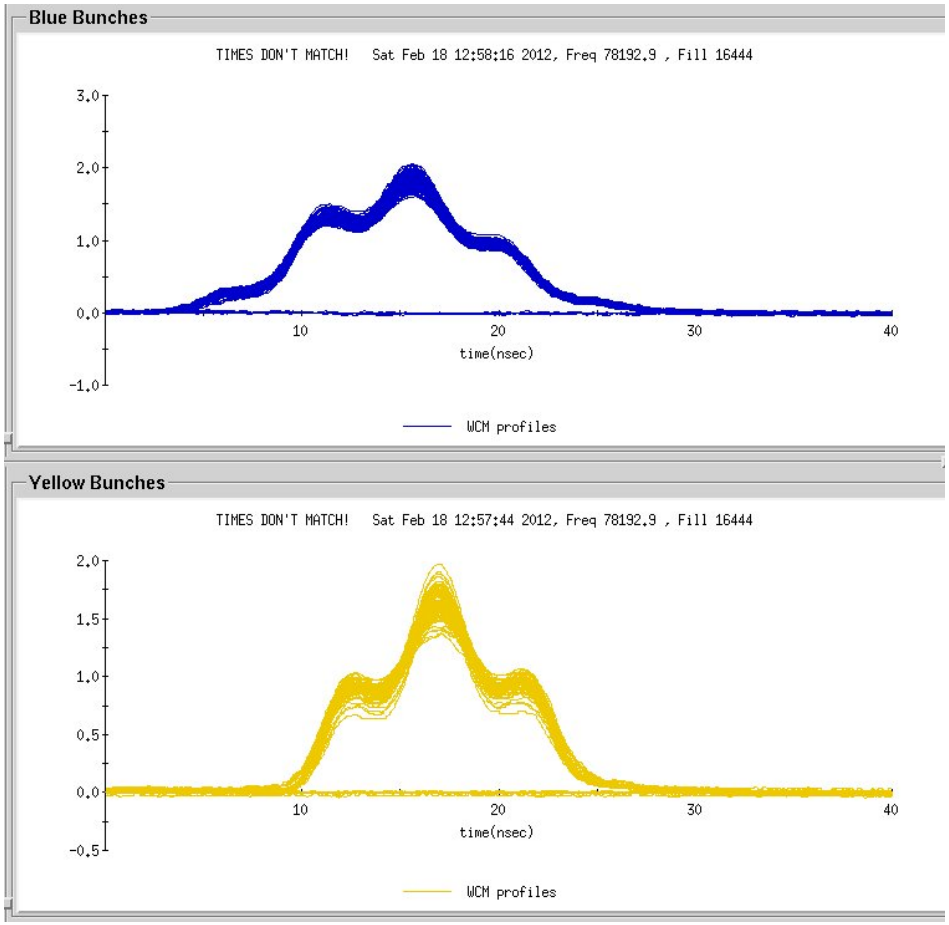

Figure 4 :

Z Bunch Profile - Inidivdual Bunches, Fill 16470

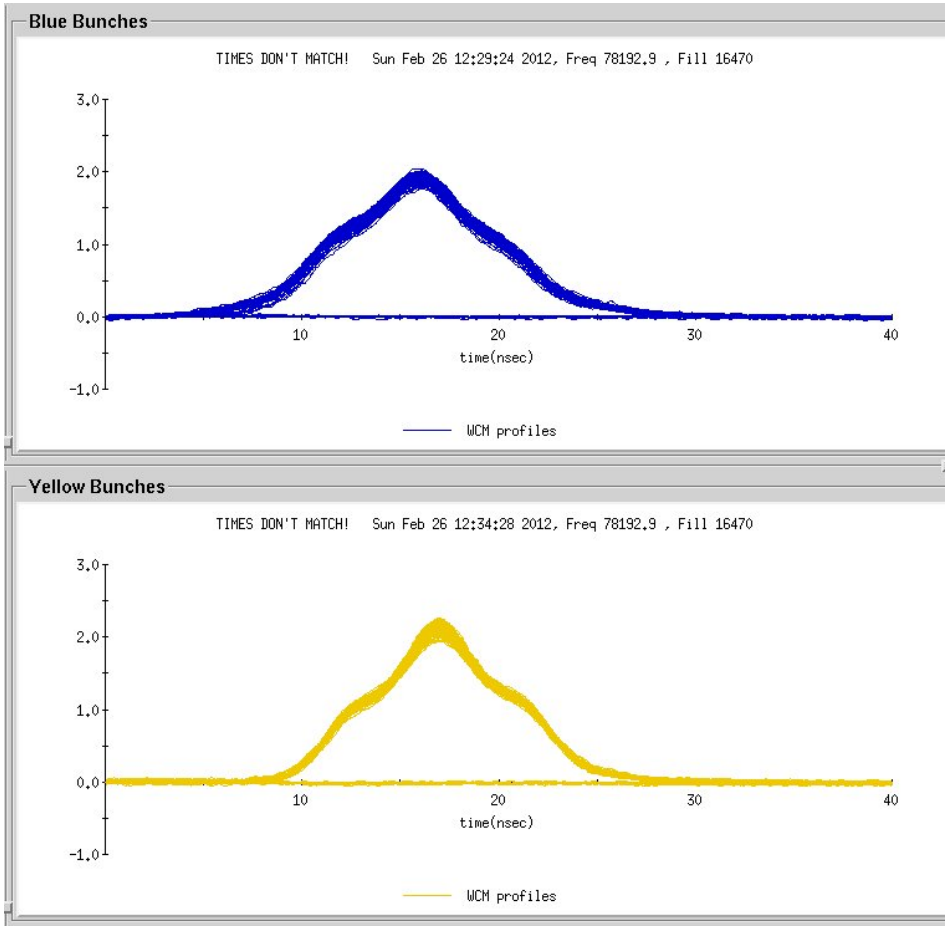

Figure 5 : Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Z Bunch Profile - Inidivdual Bunches, Fill 16514

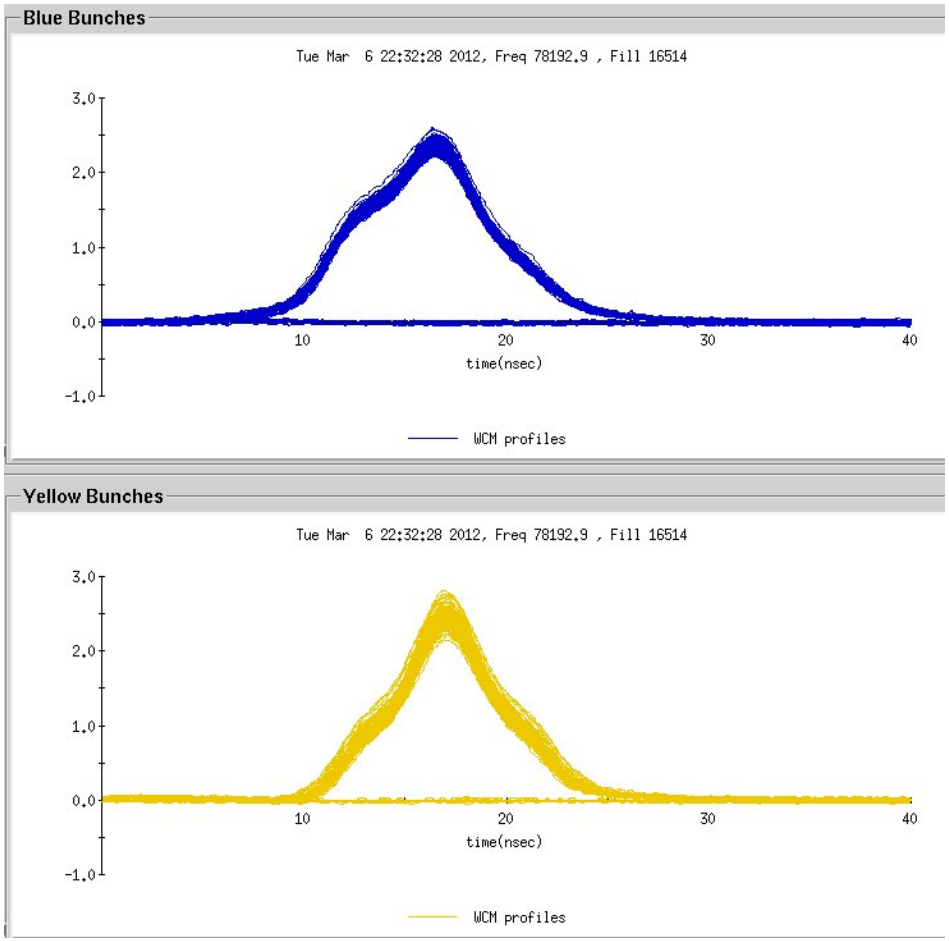

Figure 6 : Fill 16514, Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Z Bunch Profile - Inidivdual Bunches, Fill 16587

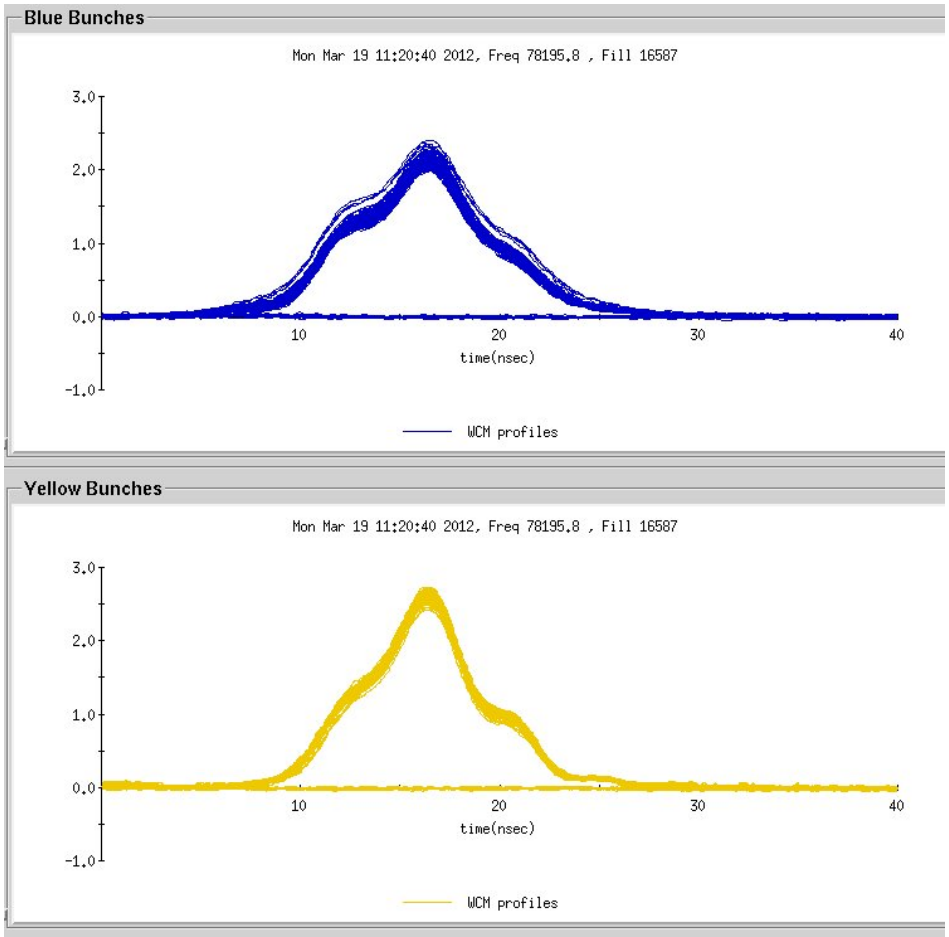

Figure 7 : Fill 16587 Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Z Bunch Profile - Inidivdual Bunches, Fill 16625

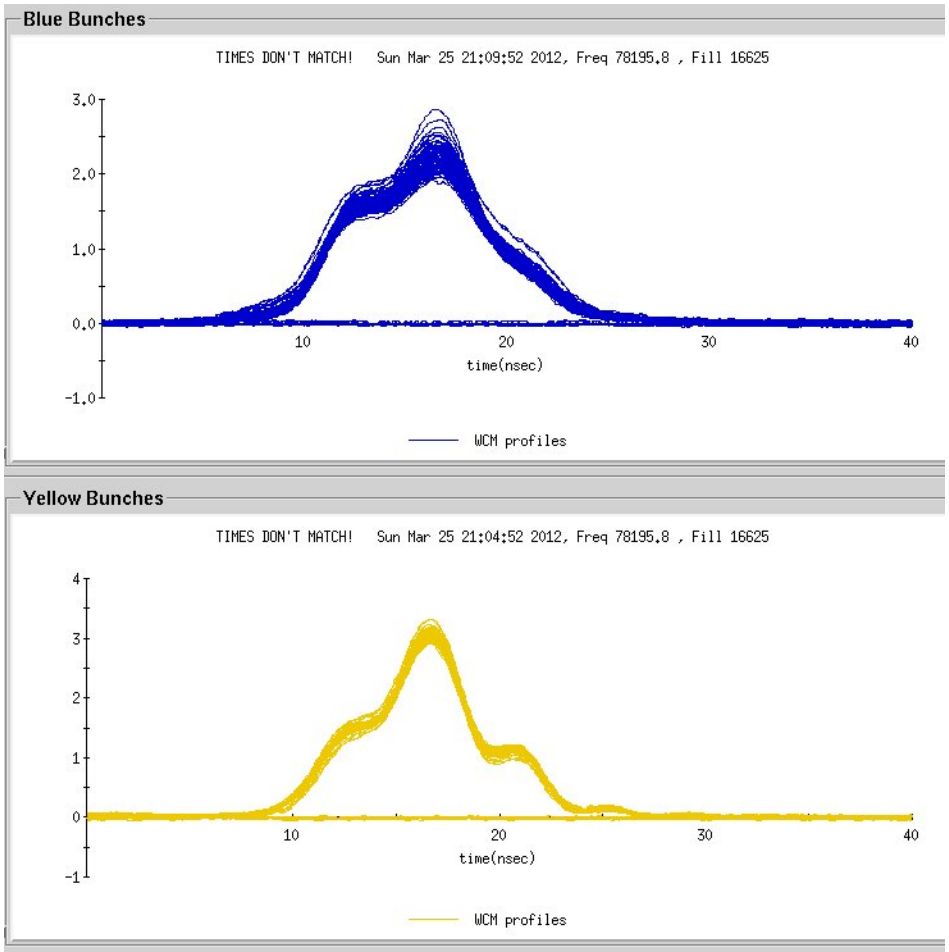

Figure 8 : Fill 16625, Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Z Bunch Profile - Inidivdual Bunches, Fill 16655

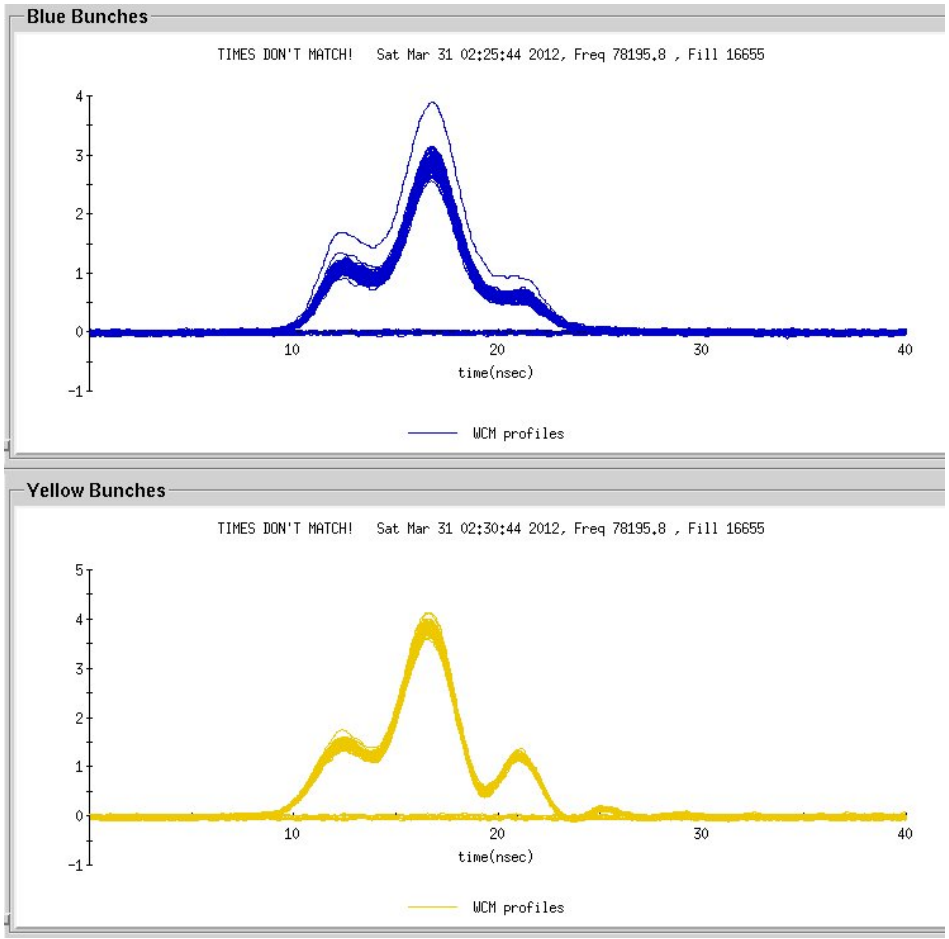

Figure 9 : Fill 16655, Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Z Bunch Profile - Inidivdual Bunches, Fill 16671

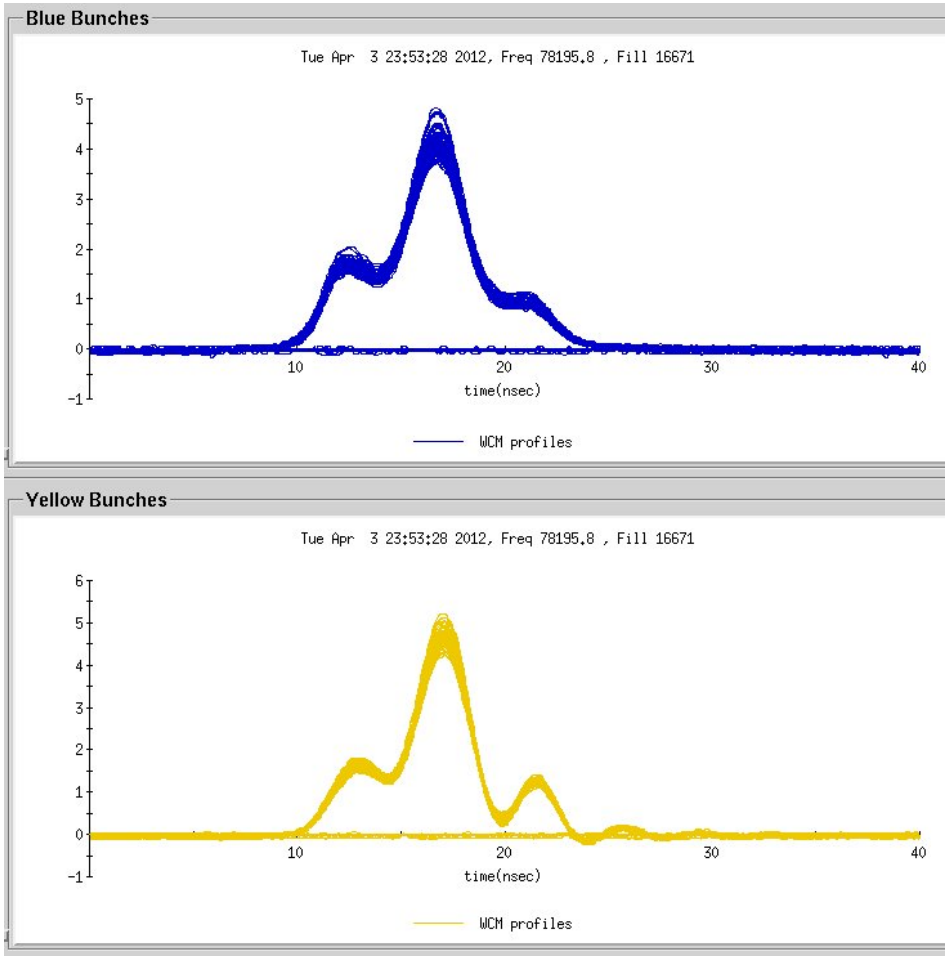

Figure 10 : Fill 16671, Blue (top) and Yellow (bottom) beam profiles for all bunches provided by Angelika Drees from CAD

Simulations With WCM Z Profile

Simulations With WCM Z Profile

- The normalized WCM distribution is stored in a TGraph object
- We can treat a TGraph as a function via spline interpolation between defined points
- TGraph::Eval does this out of the box
- With TGraph::Eval, we obtain the function-like behavior needed for transformations.
- **Caveat:** The numeric integration portion of the code consists of 172 million iterations - so anything in this loop needs to be heavily optimized to avoid impossibly long run-times.
- **Caveat:** When using simpler model for the z-bunch profile, simulation takes in total, 35 seconds - this is already getting to be long, considering that even with a computing cluster, running over many variations of a parameter space can lead to tens of thousands of simulation instances.

Simple Z Profile Simulation

For review - we have our old z-profile result for a 1000 micron scan step. Simulating this takes about 35 seconds.

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001
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

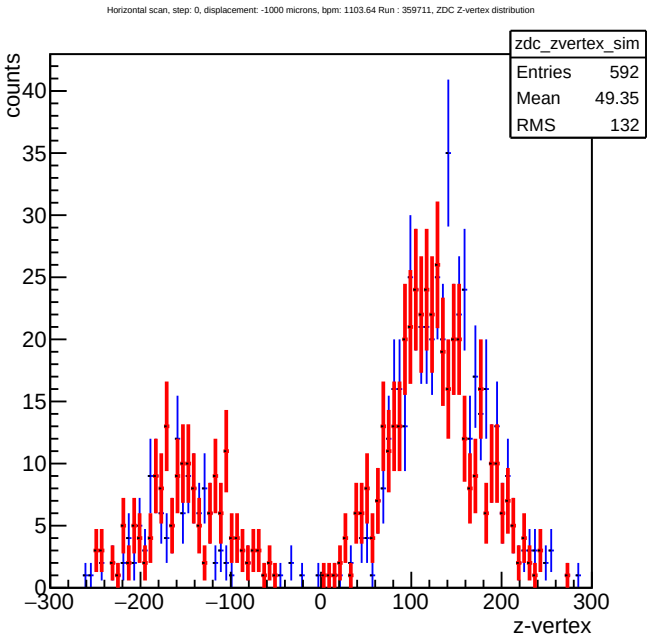

Figure 11 : Using an approximate scaled z-profile for colliding bunches

Realistic WCM Z Profile Simulation

Using the exact same simulation configuration as before, we simply replace the z-profile model with the z bunch profile taken directly from the fine binned WCM data.

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001
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

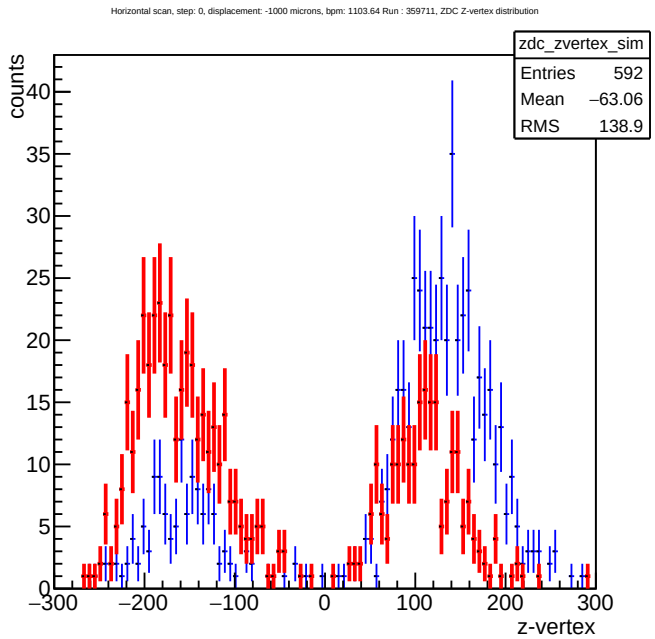

Figure 12 : Using the "real" Z Profile for colliding bunches

Realistic WCM Z Profile Simulation - Flipped Bunches

The previous profile looked like it might fit better if it were flipped, since otherwise the distriubtion implies our crossing angle from Figure 11 is wrong. Here we test if this affects the z-vertex profile by flipping the bunches.

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ -0.08e-3
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001
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

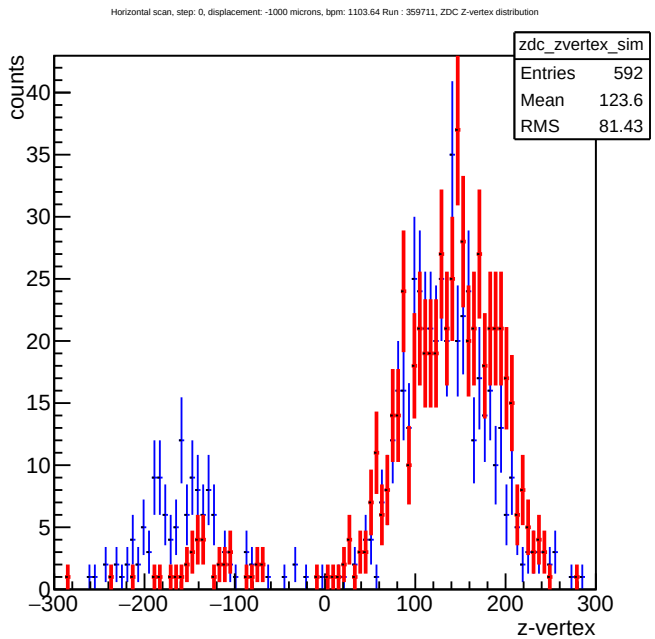

Figure 13 : Using the "real" Z Profile for colliding bunches, bunches have been flipped along the z-axis

Realistic WCM Z Profile Simulation - Positive Crossing Angle

Here, we take the "normal" orientation of the bunches, and collide them with the opposite sign crossing angle.

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ 0.08e-3
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001
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

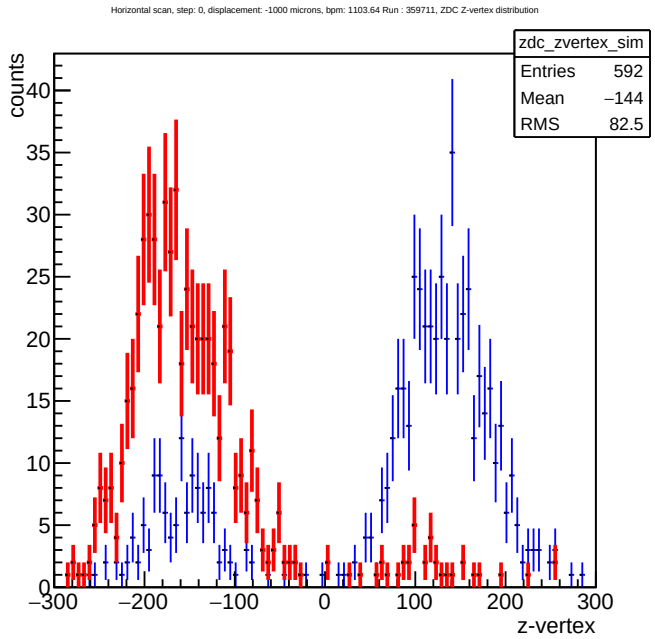

Figure 14 : Using the "real" Z Profile for colliding bunches, flipped sign on crossing angle.

Realistic WCM Z Profile Simulation - No Crossing Angle

Here, we take the "normal" orientation of the bunches and assume no crossing angle in the XZ plane.

AVG_NUMBER_IONS_BLUE_BEAM 120.029e9
AVG_NUMBER_IONS_YELLOW_BEAM 88.1677e9
BBC_ZDC_Z_VERTEX_OFFSET -9.53756
BETA_STAR 85
BUNCH_CROSSING_FREQUENCY 78213.
CROSSING_ANGLE_XZ 0
CROSSING_ANGLE_YZ 0.
FILLED_BUNCHES 107
HORIZONTAL_BEAM_WIDTH 0.0245674
MAX_COLLISIONS 5
MULTIPLE_COLLISION_RATE 0.001
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

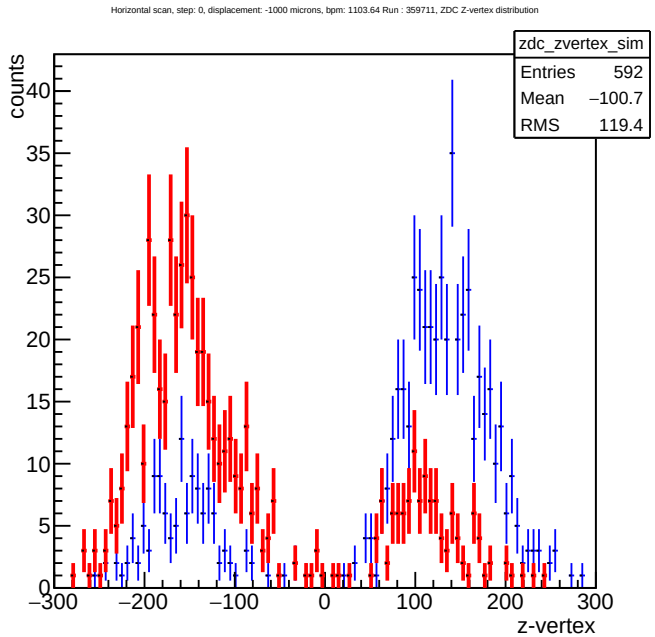

Figure 15 : Using the "real" Z Profile for colliding bunches, assuming no crossing angle

Discussion

- Why flip bunches? Because maybe I have the direction of travel incorrect!
- We can see from the comparison of using a simple (incorrect) model for the bunch z-profile can drastically alter the results of the simulation
- We can see that the crossing angle is perhaps not well nailed down.
- The problem now is that using this new bunch model has increased simulation time from 35 seconds to 20 minutes.
- Reducing the run time of the simulation will drastically speed up progress.
- The Z-Profile of the bunch is extremely important to getting the right answer - and incorrect profile can make affects (such as a crossing angle) appear to happen when there is none.
- After substituting in a different z-profile, I have to triple-check the simulation code, to make sure its doing the right thing.

Possible Optimization?

The simulation takes 20 minutes, which is due entirely to how TGraph::Eval works. It does the following:

- Performs a sort on three separate arrays representing the data in the TGraph (if specified)
- Performs a linear search through the TGraph internal arrays for the nearest x-value
- Performs a spline-interpolation to obtain the an approximate y-value

The typical WCM profile consists of 2100 points, and as seen in Figure 3, this corresponds to a z-vertex resolution of 1.4 cm.

Possible Optimization?

- The features of the WCM distriubtion in 3 seem to have a characterstic resoltution scale that is larger than 1.4 cm.
- The main issue is that we calculate coordinate transformations based on the crossing angle, which is a parameter we wish to vary over the simulations, rending precalculation impossible - **i.e. we cannot escape interpolation when using data directly.**
- My guess is the linear search impacts run-time the most, followed by spline approximation.
- Might also go faster if we made WCM data more coarsely binned
- Linear search: $\mathcal{O}n \rightarrow 2100$
- Binary search: $\mathcal{O}log(n) \rightarrow 3.2$
- Probably pretty big improvement
- Implement density as an STL object to take advantage of faster searching algorithms.

Conclusions

Conclusions

- "Real" bunch profile is available and simulation is running
- Heavy optimization needed - and may ultimately speed things up quite a lot
- Need to re-evaluate the rest of the luminosity calculation loop, the transformations to x, y, z, $\rho(x, y, z \pm ct)$ and $\sigma_{x,y}$ do not seem totally consistent with literature, need to check that I'm not missing a simplification or something.

The End!

Thanks for your attention and questions!