Fermilab

UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Angular scan and track correction

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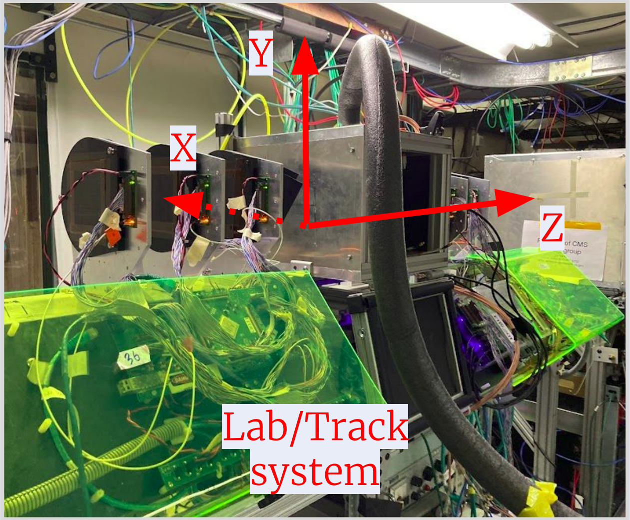
Context

The position of the hit (interaction of the proton with the sensor) is interpolated using the tracking system, which gives us some proton's track parameters: **intercept and slope of the track's projection over xz and yz planes**.

This interpolation needs to take into account the actual position of the sensor (i.e. possible tilts that displace the sensor's plane of an ideal z=constant position.)

Previous analyses were made using an initial correction that only considered a rotation around the z-axis (expected to have the highest impact in the calculation.)



Alignment procedure

Our objective is to find the hit coordinates as seen by the sensor. The strategy for doing so is:

1. Find a mathematical expression for the hit in the sensor surface, but **in the laboratory frame of reference**.
2. Find a matrix transformation from Laboratory's frame to Sensor's frame.
3. Apply this transformation to the hit position.

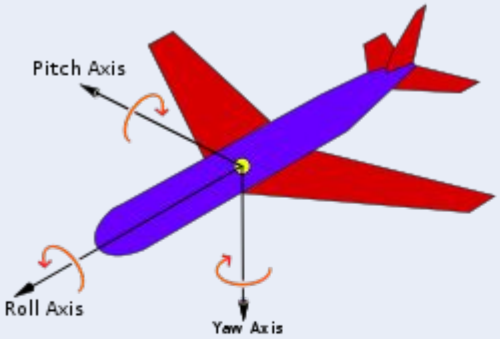
Considerations:

- The sensor is known to be somewhere in the central box, but we need an exact Z position of reference → We use Z_C.
- The rotations are defined around a certain point in the sensor → (X_C, Y_C, Z_C).
- These four quantities $(Z, \alpha, \beta, \gamma)$ must be hard coded → **Multidimensional scan**.

Differences with previous method

The rotation implemented initially was only around a single axis (z-lab). Later, a first try for this 'Multi Dimensional Scan' used an 'Euler rotation' approach, which led us to a scan that wasn't successful, given two angles too correlated.

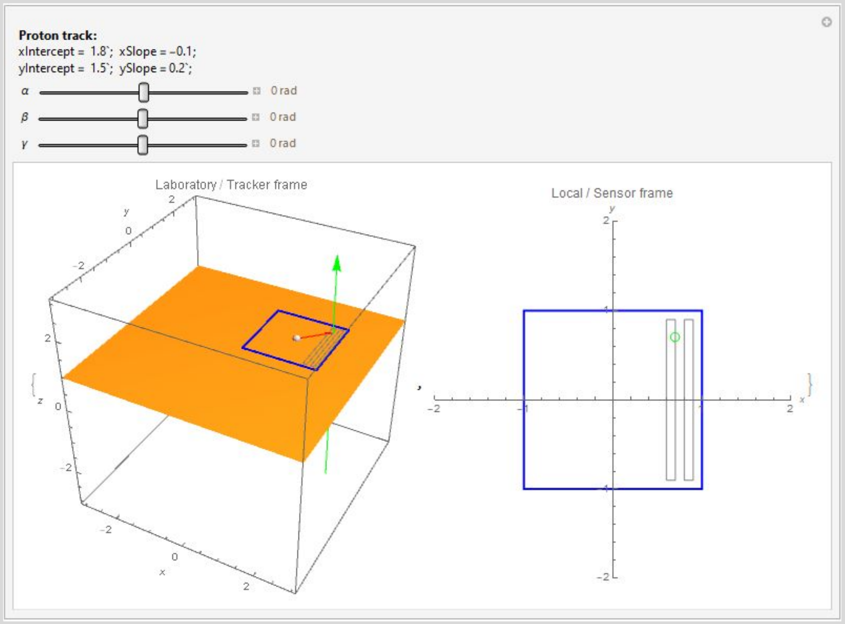
The best way of make this analysis was using the so called 'Tait-Bryan Angles', also known as nautical angles, where the rotations are made around local axes and only once per axis.



Visualization

The animation shows the rotations around the axes and the 'translation' into the sensor's local coordinates.

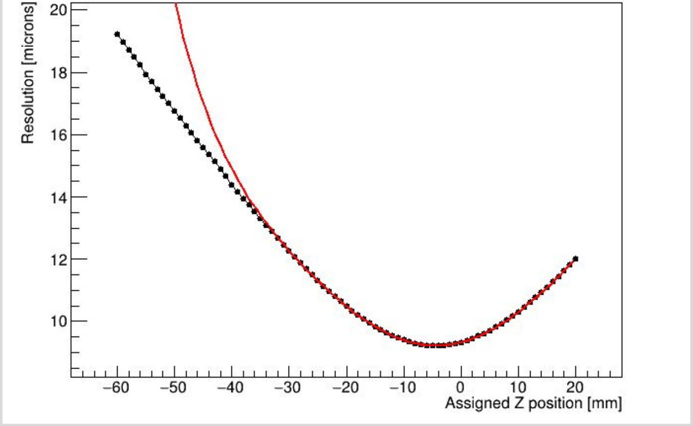
Note that an angle in the proton's track generates a hit in a non-intuitive position.



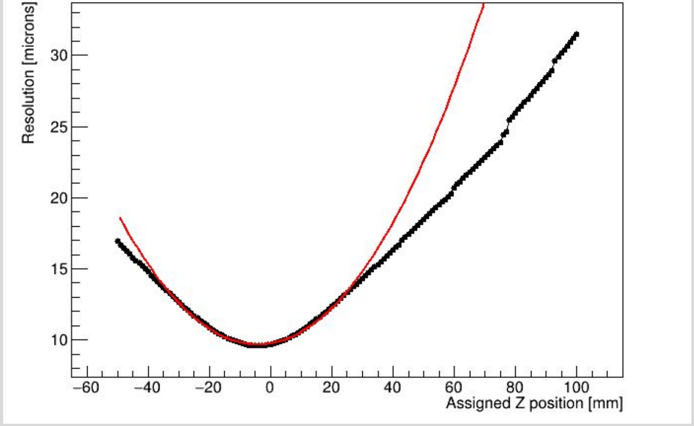
Comparison with old scan

To check the consistency of this method with the original, the ZScan is compared (after the α rotation, i.e. both methods have only a rotation around z axis) using the new data taken for the **BNL2021 medium** sensor.

New method
Minimum at ~ -4.36 mm



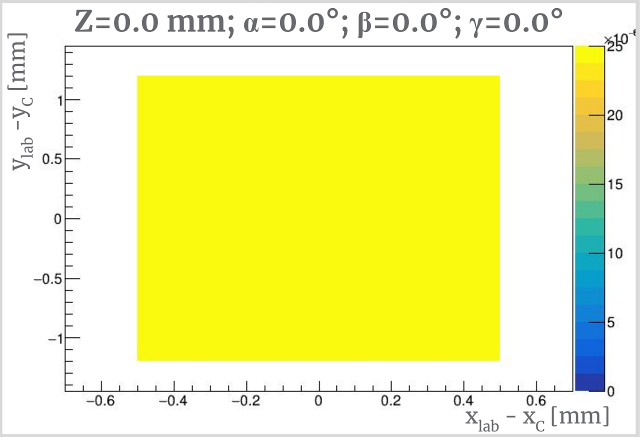
Old method
Minimum at ~ -4.23 mm

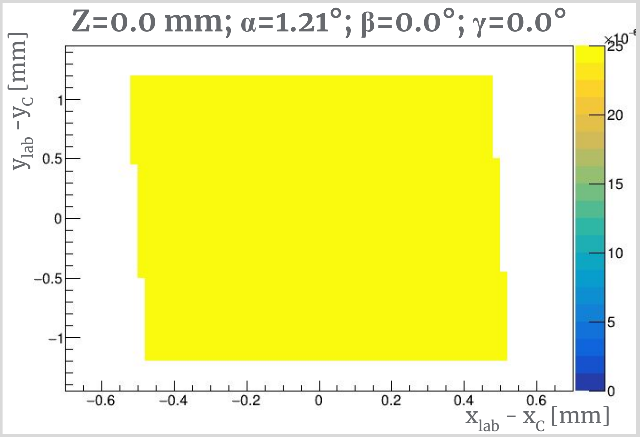


Effects of the rotation in the laboratory frame

The figures below show the projection over a Z = Constant plane (imagine it as the ‘shadow’ produced if we illuminate the sensor from behind) for different angles’ values in the laboratory frame.

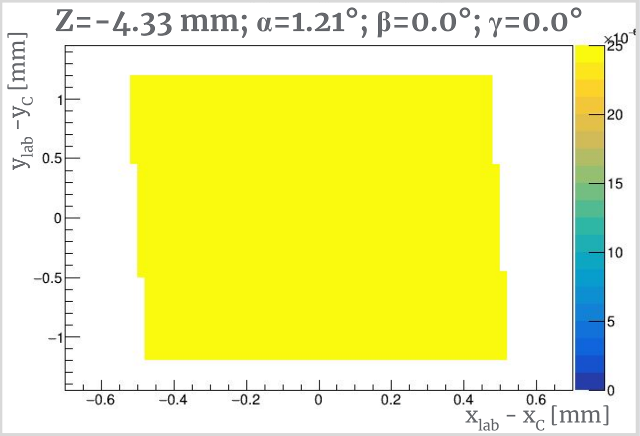
To get a feeling of the depth, the colors represent how far is certain section of the sensor displaced from the constant $Z = Z_C$ position.

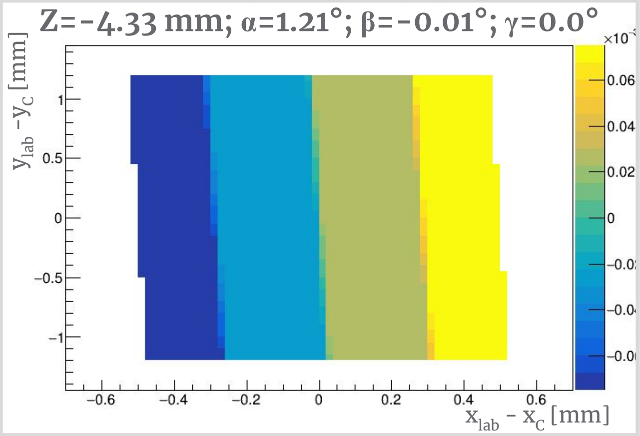




Effects of the rotation in the laboratory frame (continued)

We can see that choosing a set of angles has an effect in the sensor's position! So the implementation seems to work as expected.

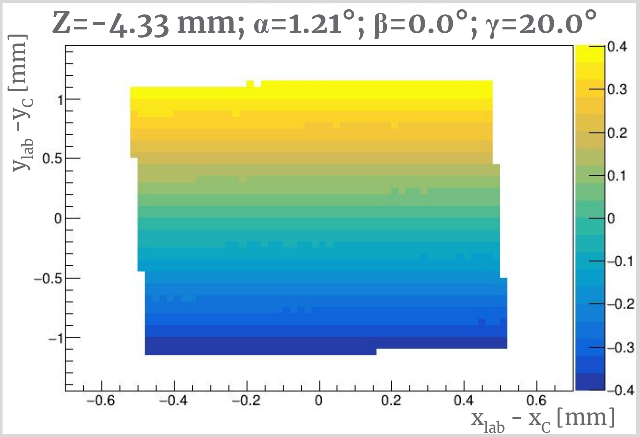


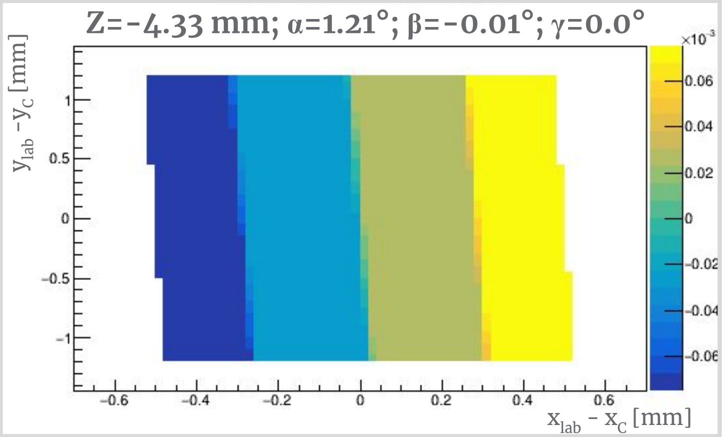


Limit cases

To be completely sure of the effects a rotation has in what the tracker sees, some ‘extreme’ values were tested.

Note that big angles make this projection to shrink, as expected.





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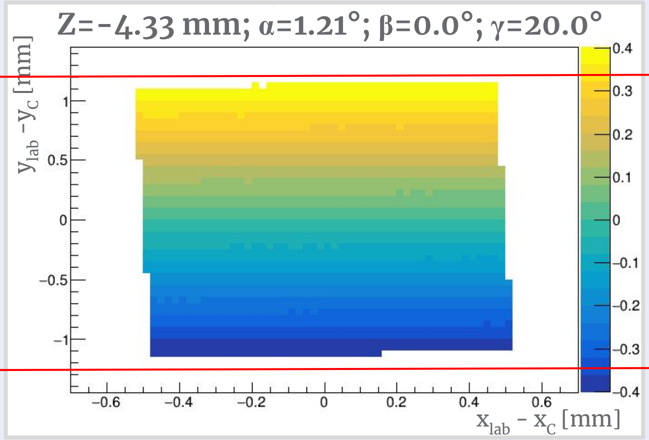
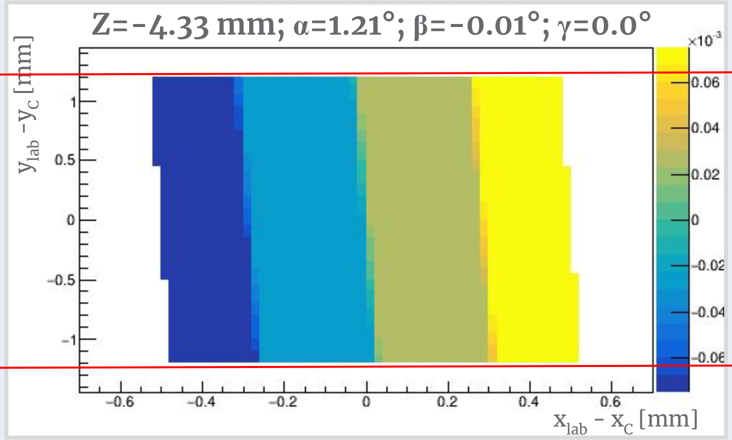
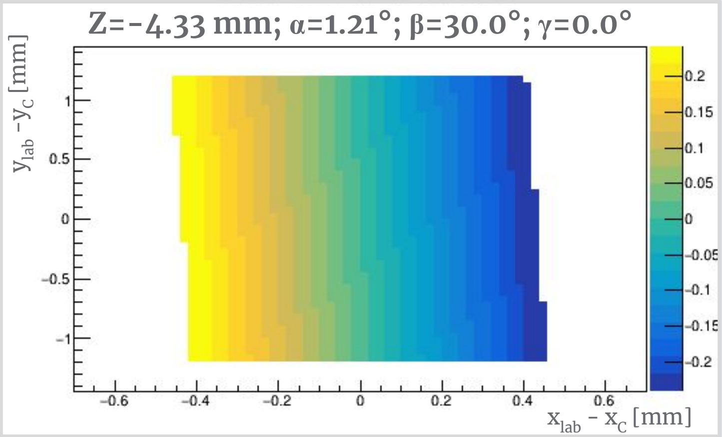
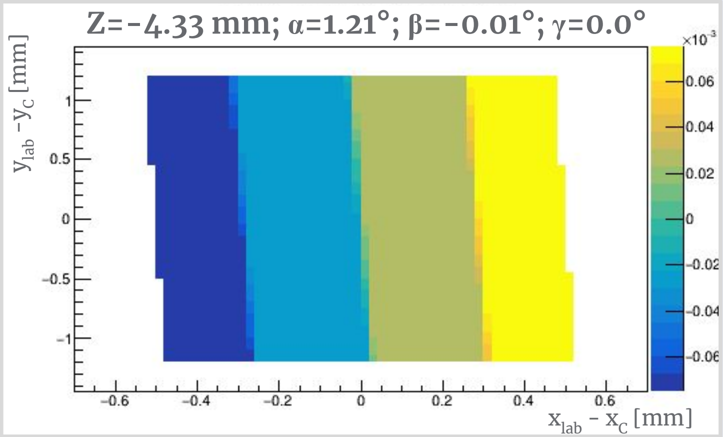




Limit cases (continued)

The same shrinking effect can be seen after rotating around y-axis.



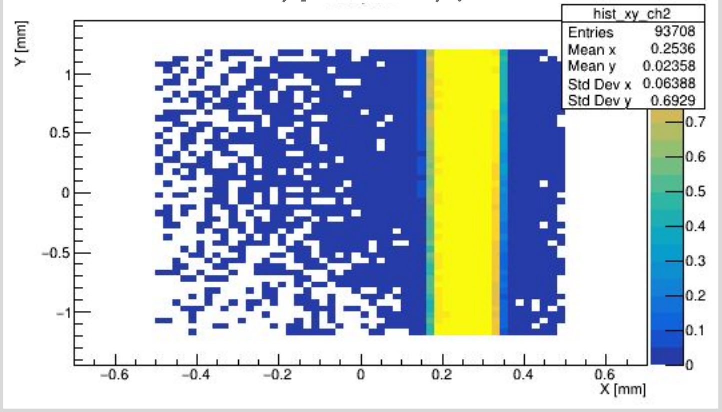


Widening & efficiency

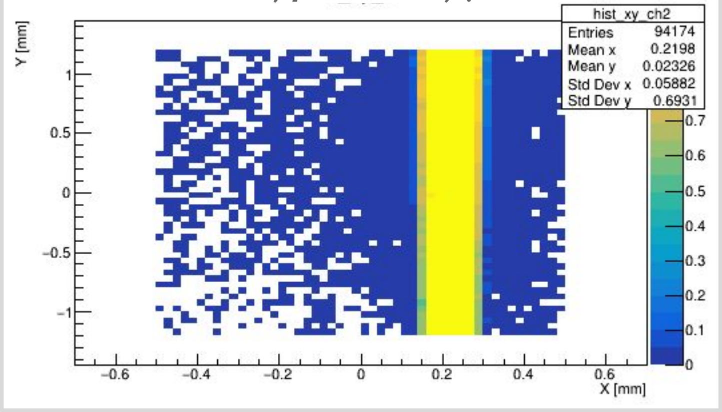
The most dramatic effect over the resolution among the angles comes from α, but the angle β has a direct effect on the strips: the pitch and strip width may be different. This affects the strips' center position and the parameters used for the charge sharing!

The efficiency plots for channel 2 show this 'widening' effect **in the sensor frame**.

α=1.21°; β=30.0°; γ=0.0°



α=1.21°; β=−0.01°; γ=0.0°



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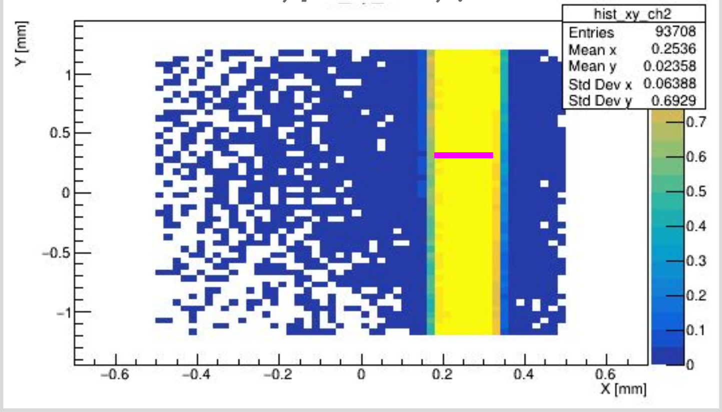

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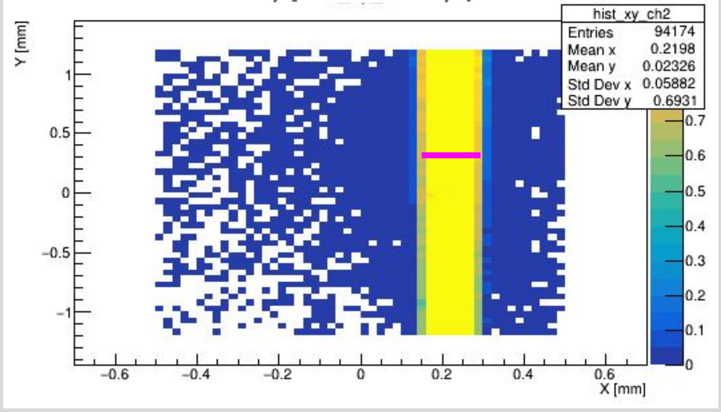


“Defining geometry” process

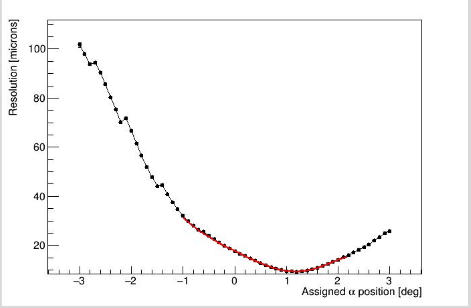
1. Look at data files and define initial parameters:
    a. indexToGeometryMap, geometry, acLGADChannelMap, stripWidth, pitch
    b. sensorCenter, sensorCenterY, xmin, xmax, ymin, ymax, sensorEdges
2. Run InitialAnalyzer:
    a. Get strip centers → FindStripCenters.py → Update Geometry2022
3. Run Analyze:
    a. Get recoParameters → DoPositionRecoFit.py → Update Geometry 2022
    b. Re-run Analyze if parameters change
4. Run Align:
    a. Get best α, Z, β, γ, in that order
    b. If at the end α has changed too much, re-run
    c. Check *position_local* and update sensorEdges if necessary
5. Re-run InitialAnalyzer:
    a. Check parameters don’t vary too much
    b. If so, re-run all again

Align: First iteration
(Z=0.0, α=0.0, β=0.0, γ=0.0)

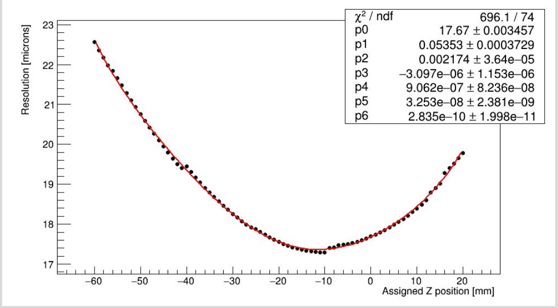
We start with all four parameter set as zero.

The first iteration shows the greatest impact in the resolution is produced by the choice of α. We previously noted that tuning that value first is the best option since, for instance, the Z minimum changes depending on this.

α Minimum at ~ 1.18°



Z Minimum at ~ −11.36 mm

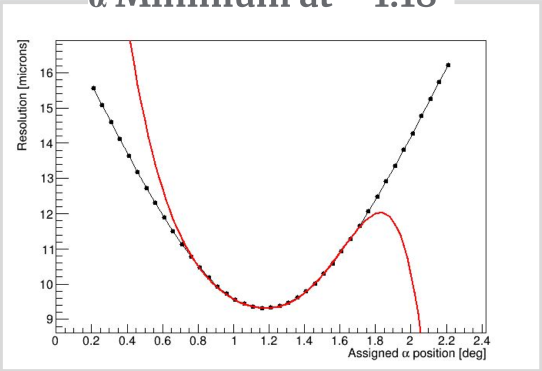


Align: Second iteration
(Z=0.0, α=1.18, β=0.0, γ=0.0)

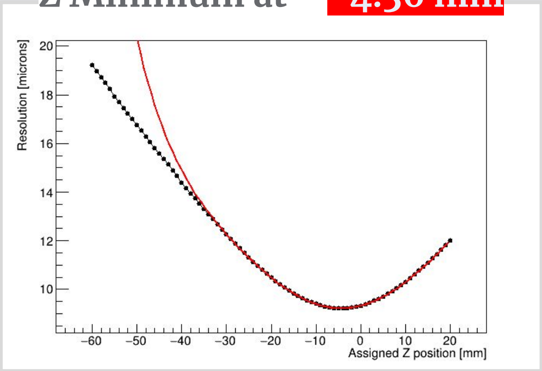
We need to confirm that the previous minima don't change too much after each iteration. This is the case for α.

Z gets impacted by this change! (Why so dramatically?)

α Minimum at ~ 1.18°



Z Minimum at ~ -4.36 mm

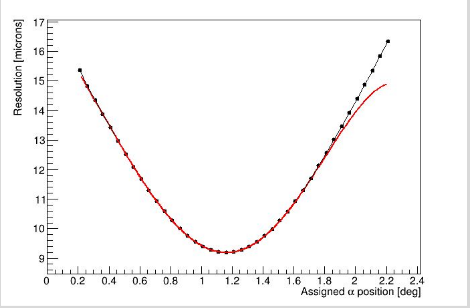


Align: Third iteration
(Z=-4.36, α=1.18, β=0.0, γ=0.0)

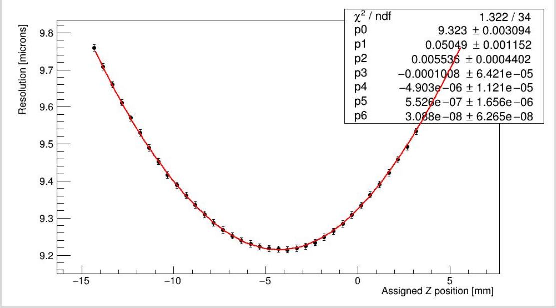
This time the β angle is slightly shifted from zero.

Note an small displacement in the previous parameters, but these changes are not significant.

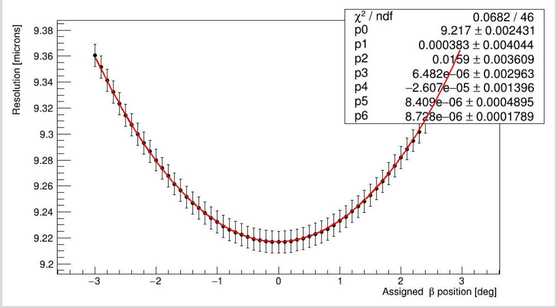
α Minimum at ~ 1.16°



Z Minimum at ~ -4.26 mm



β Minimum at ~ -0.01°



Conclusions

- The effect of the angles is not negligible, and their impact can be summarized as: α >> β > γ.
- The β angle affects other hard coded parameters, for instance those used in charge sharing, so they must be recalculated.
- The apparent not utility of γ should be revisited since it might affect the strip length, which in turn might have an impact in the time/velocity of the signal.
- The proper order to extract these scanned parameters starts with all set as zero, then one obtains α, later Z, and finally β. In case of getting γ different from zero, extract its value at the end and check that the other parameters are not affected.

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