REU Final Presentation: VERITAS Update

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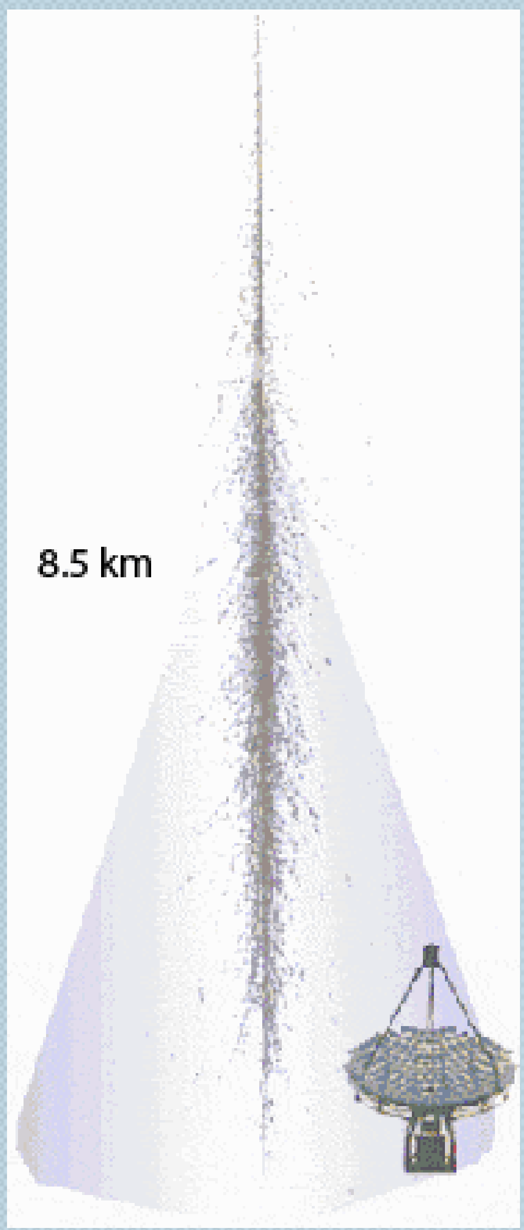
Very Energetic Radiation Imaging Telescope Array System

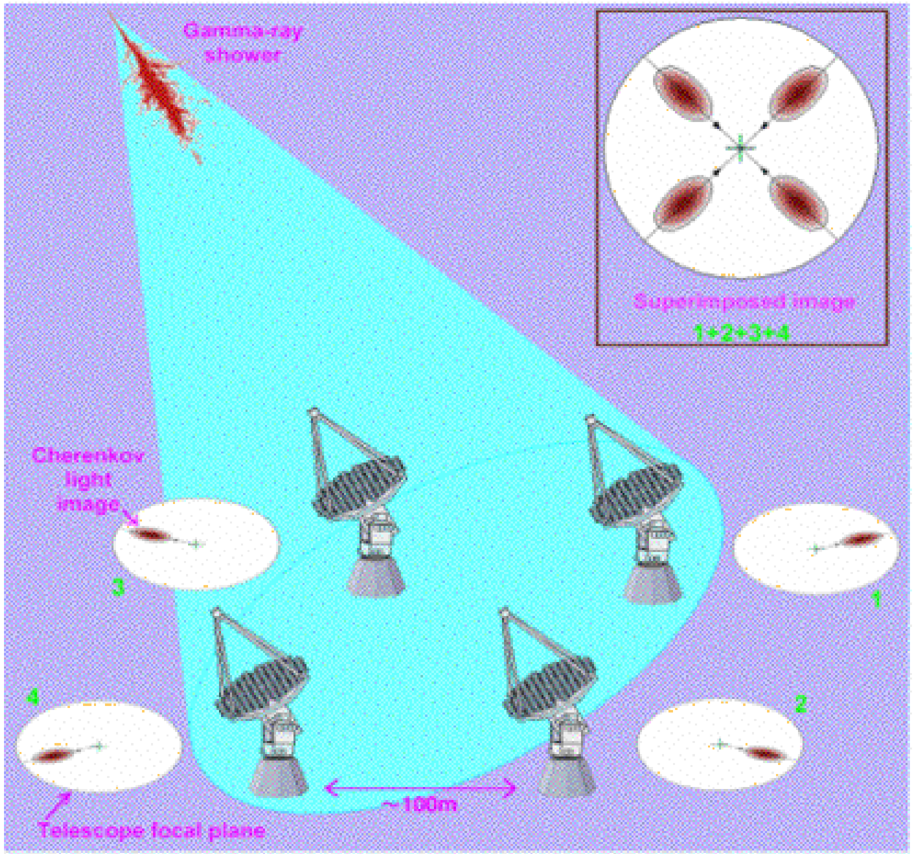
- Ground-based gamma-ray observatory
- Located at the Fred Lawrence Whipple Observatory in Arizona
- Can be used to study black holes, pulsars, supernova remnants, globular clusters, **galaxies, dark matter, and other unidentified sources.**

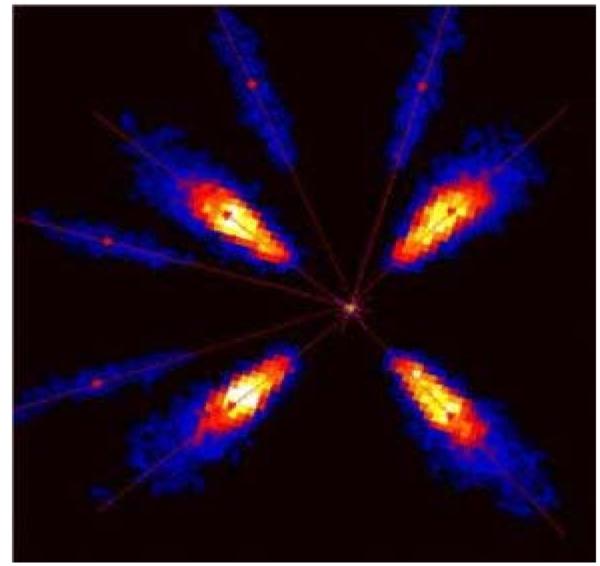
- Davies-Cotton design
- Facets have a 24 meter radius of curvature
- Facets mounted on a 12 meter diameter dish with a 12 meter radius of curvature
- ~350 mirror facets which have a diameter of .61 meters
- Camera is at 12 meters from mirror
- Use 499 photomultiplier tubes as pixels
- Detects 50 GeV-50 TeV, with maximum sensitivity between 100 GeV and 10 TeV



GAMMA RAY SHOWERS

- VERITAS cannot detect gamma rays directly because they are converted into an electromagnetic cascade in our atmosphere.
- As a gamma ray interacts with an air nucleus in the atmosphere, it converts into an energetic electron and positron pair.
- The electron and positron cannot go far before interacting with more particles.
- The secondary particles created have such high energy that they move faster than the speed of light in air.
- This creates a shockwave and then Cherenkov radiation in the form of blue light.
- VERITAS detects the blue light from this process.





- The telescopes will detect an elliptical shape if it is a gamma ray. (Adversely it would see a wide range of shapes if the source had been a cosmic ray.)
- To find the source of the gamma ray, you can trace the ellipses back towards the center and where they cross is the location of the source.
- Having four telescopes helps to discriminate against background noise and increase sensitivity.

Simulations

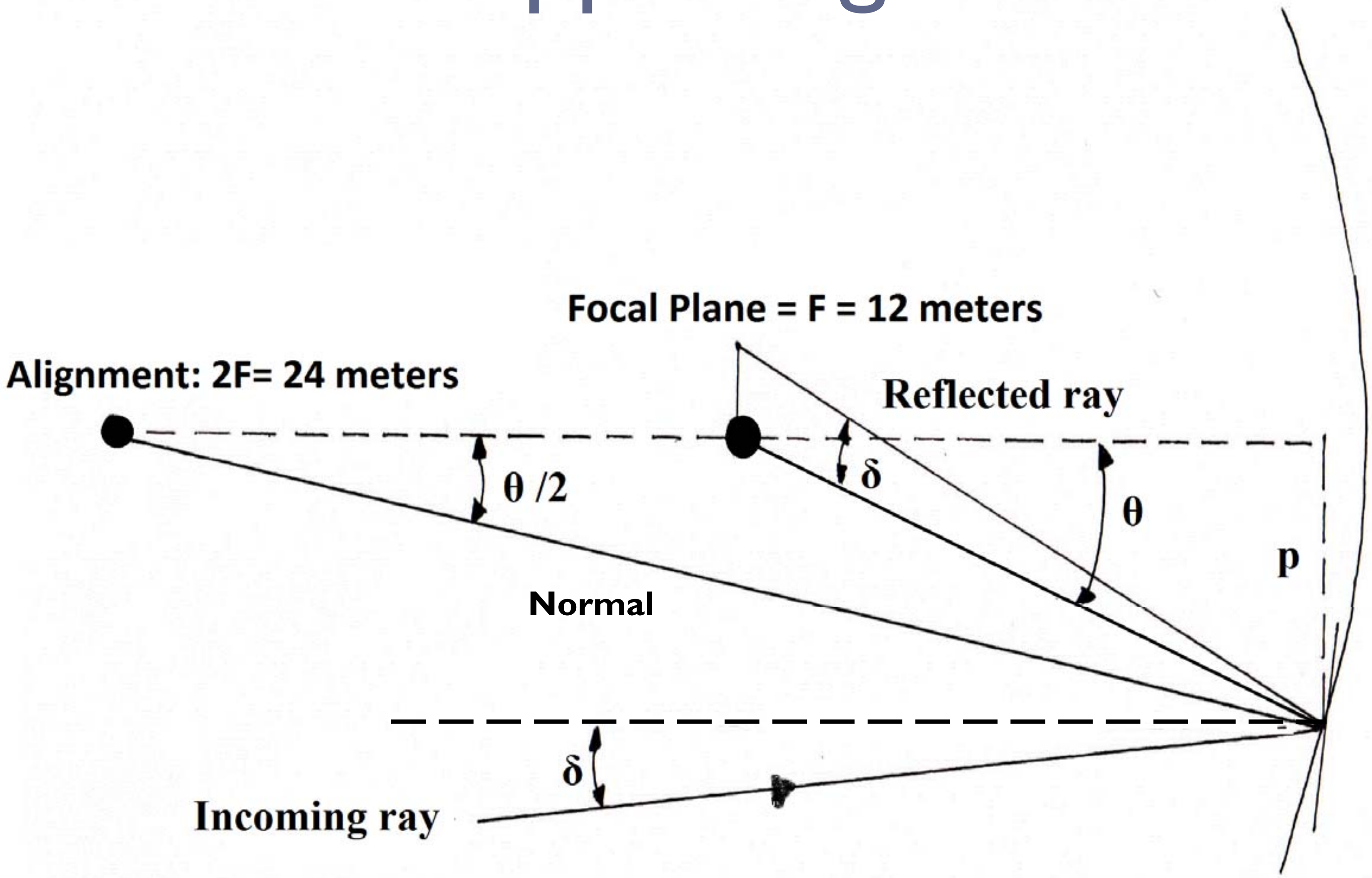
- KASCADE
- Monte Carlo to simulate photons randomly hitting the facets
- Used vectors for raytracing
- Changed the location of the source in the sky, facet jitter, focal plane location and alignment, facet location, and Whipple versus McGill alignment.
- Simulations analyzed using "root"

What is my job?

- Testing each update to the code
- Set the parameters of the simulations and run them on a Linux terminal
- Use “root” to collect information from simulations
- Use “root” in Linux to make plots with the data
- Analyze the results
- Create power points and wiki pages to share the research

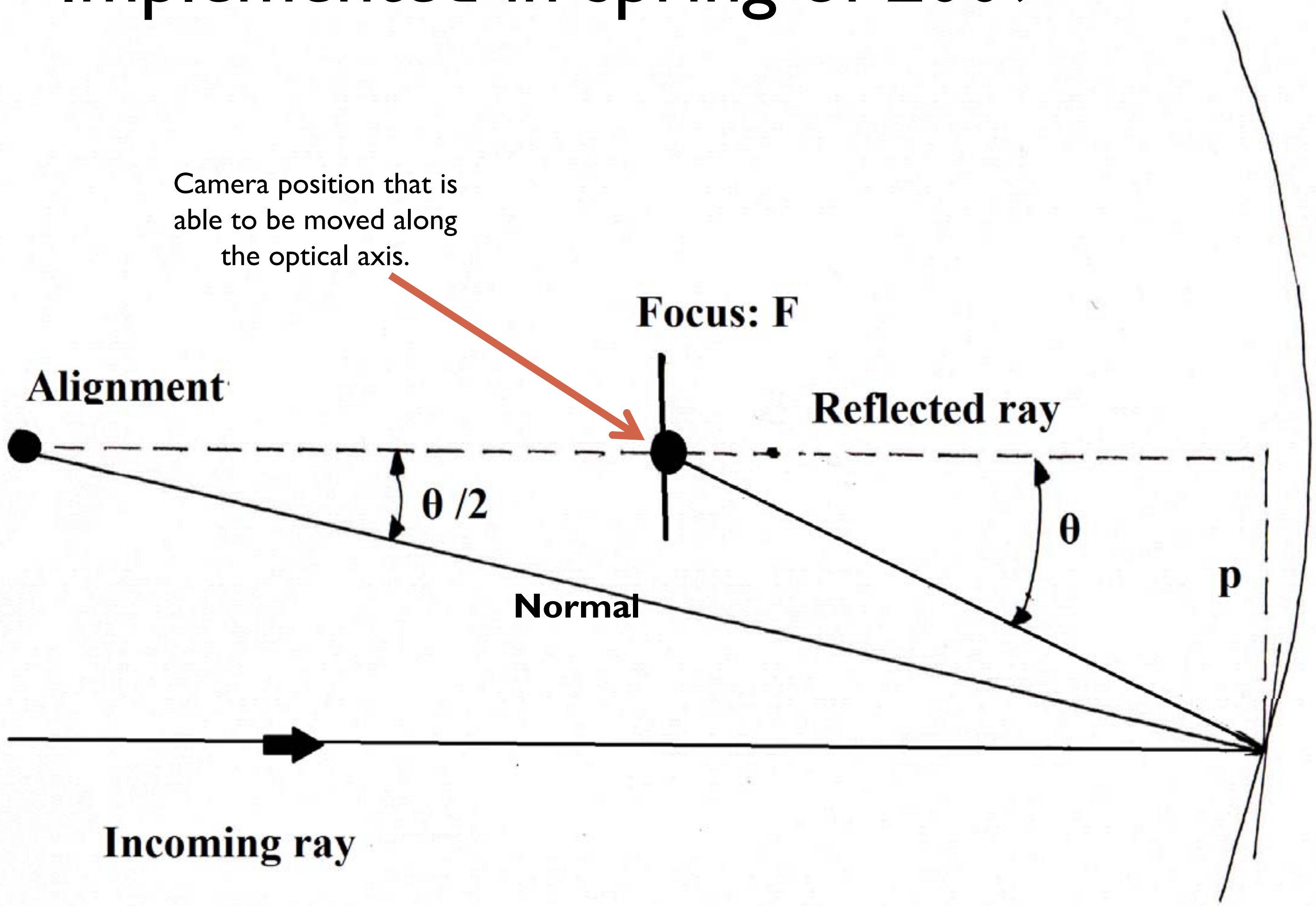
TYPES OF ALIGNMENT

Whipple Alignment

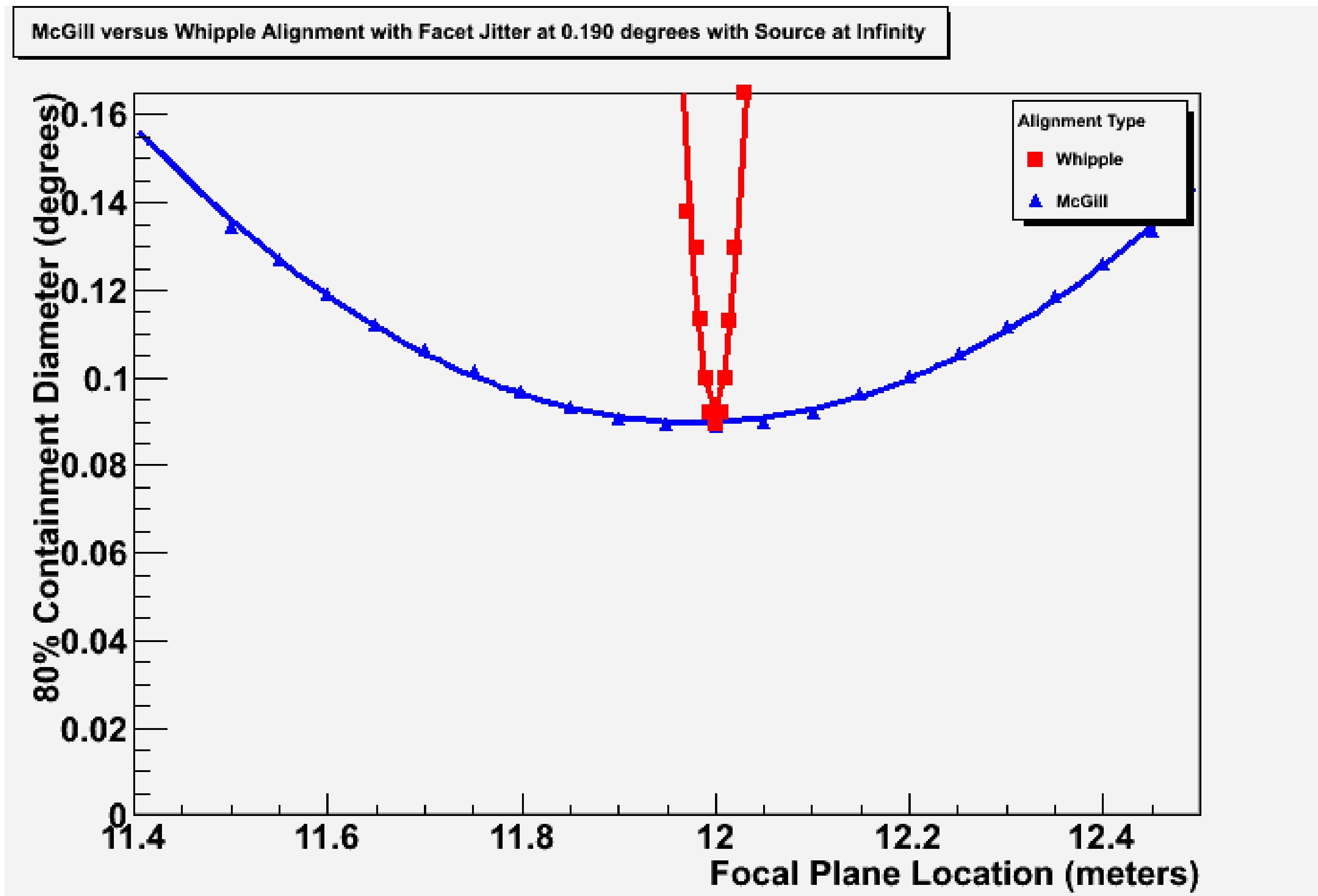


McGill Alignment

- Implemented in spring of 2009



Whipple versus McGill Alignment

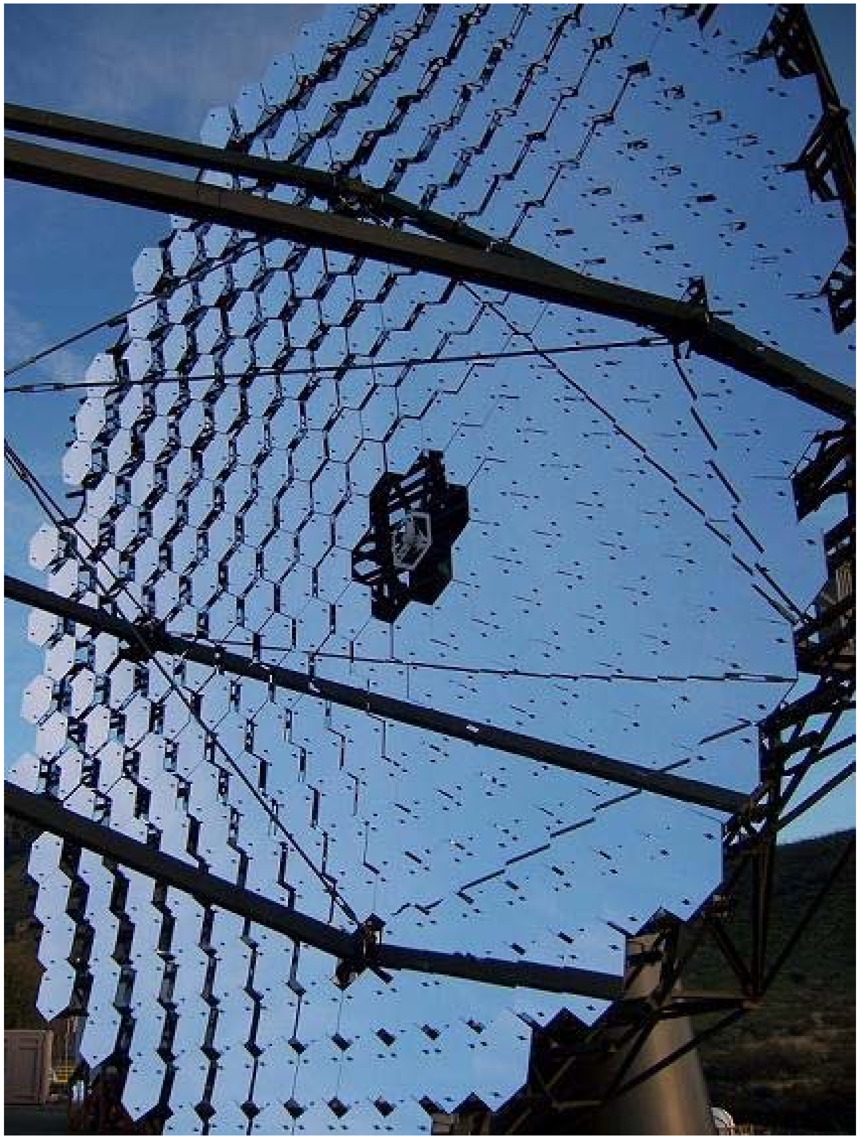


This shows that the Whipple and McGill have a similar minimum but that McGill has a wider range of acceptable focal plane positions.

Facet Jitter

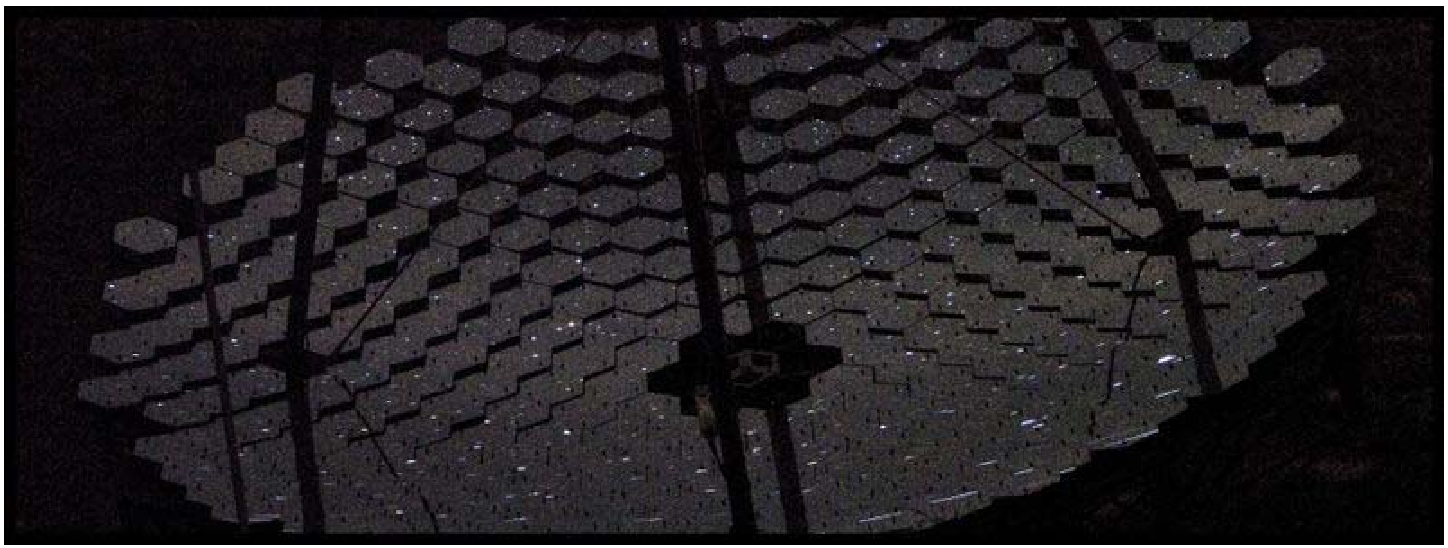
In order to make our simulations resemble more closely real results from the telescope, we added a facet normal jitter. This redirects each of the individual mirrors in each of the cardinal directions.

Our usual jitter angle is 0.0095 degrees.



Facet Location

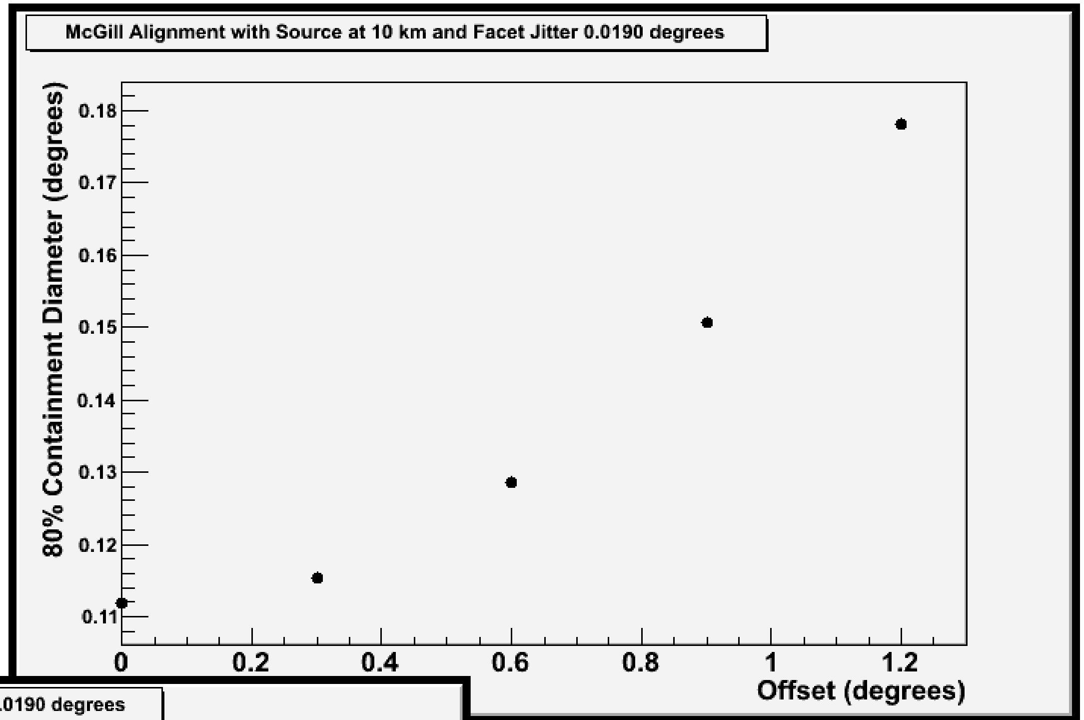
- Hillas method: randomly produces facet where a photon hits.
- New method: reads in a file with all the facet locations so that a photon hits a "real" facet within the simulation.

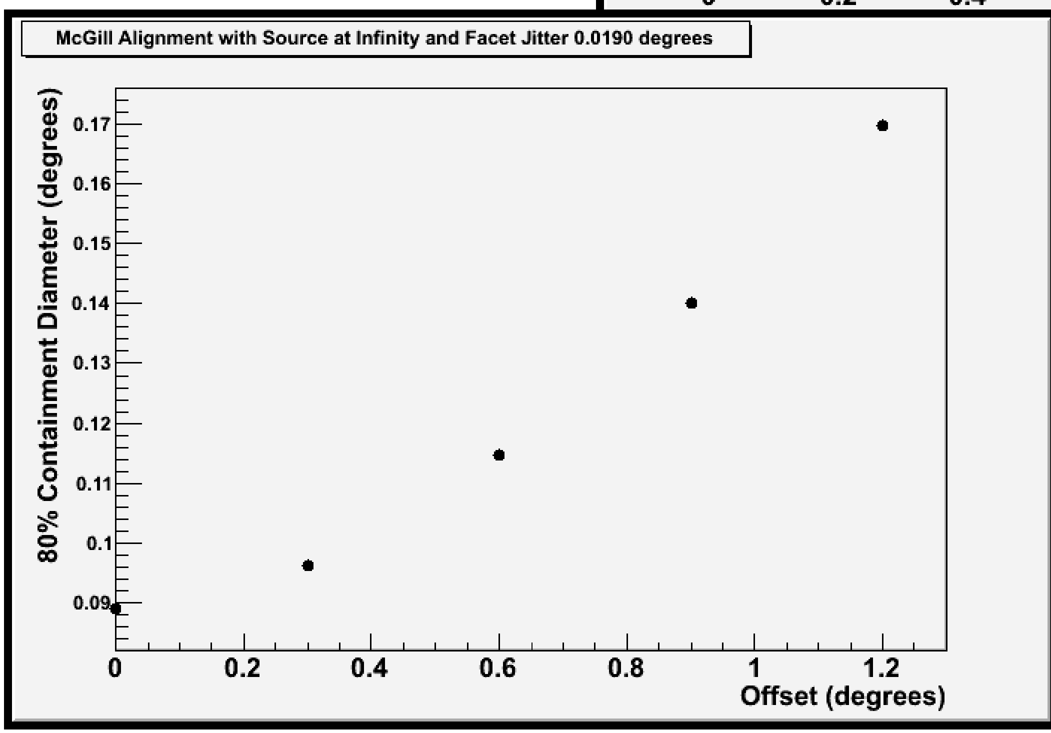


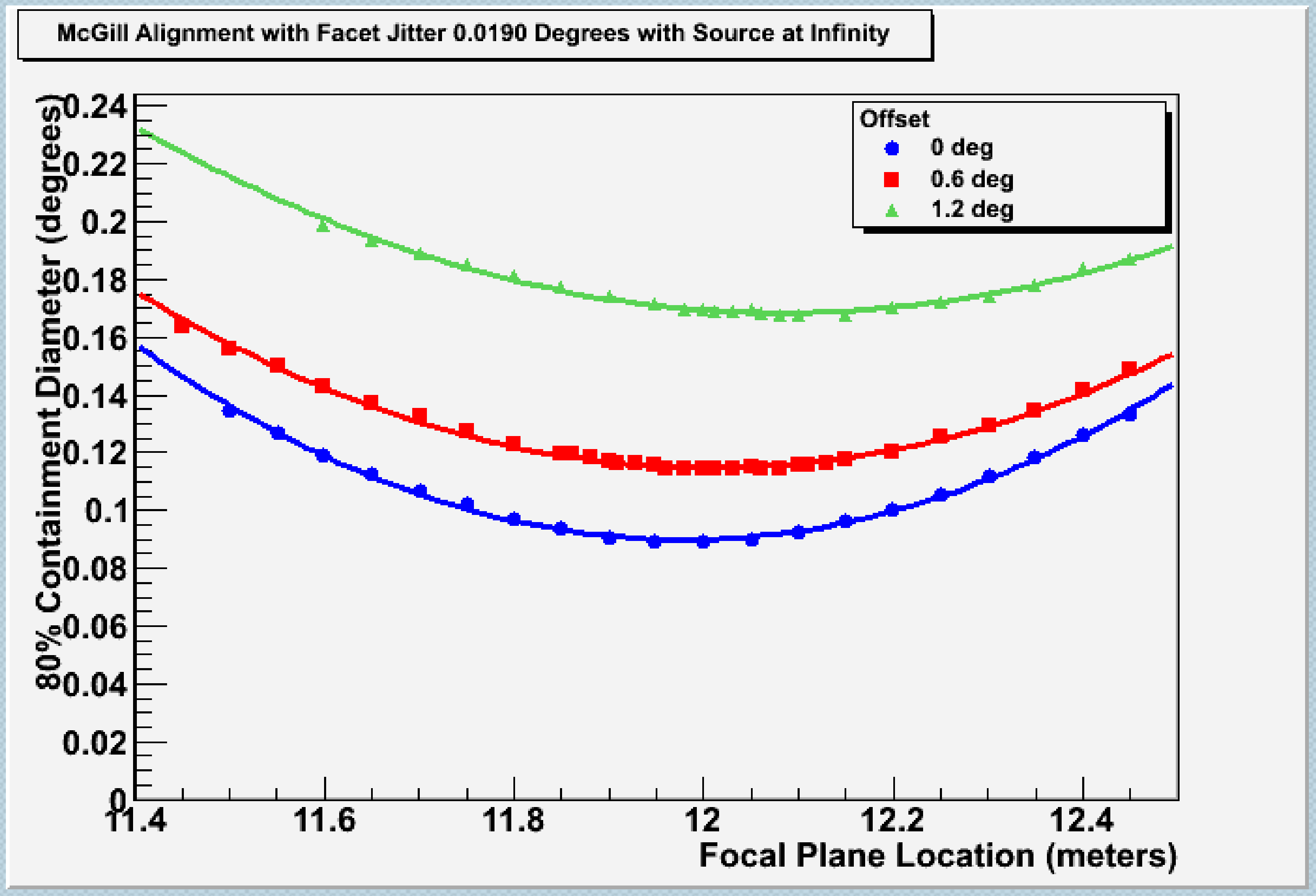
FOCAL PLANE UPDATE OF VERITAS

Is it beneficial to move the focus from infinity to the gamma ray shower maximum?

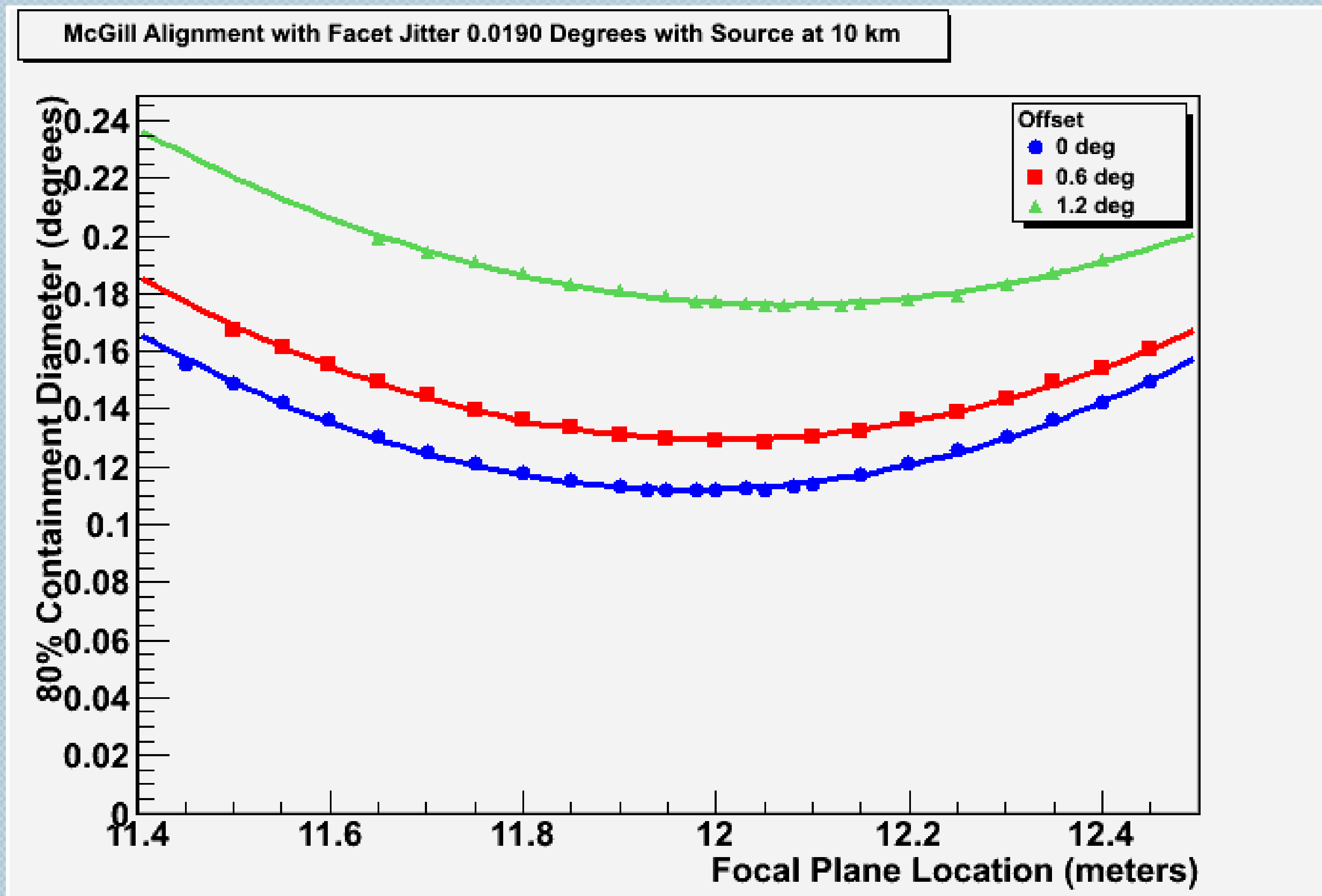
Both use McGill Alignment but one has the source at infinity and the other at 10 km. They both have the same pattern of gradually increasing the containment diameter but at infinity the diameter is 0.09 degrees. While the source at 10 km has its smallest radius at 0.112 degrees.





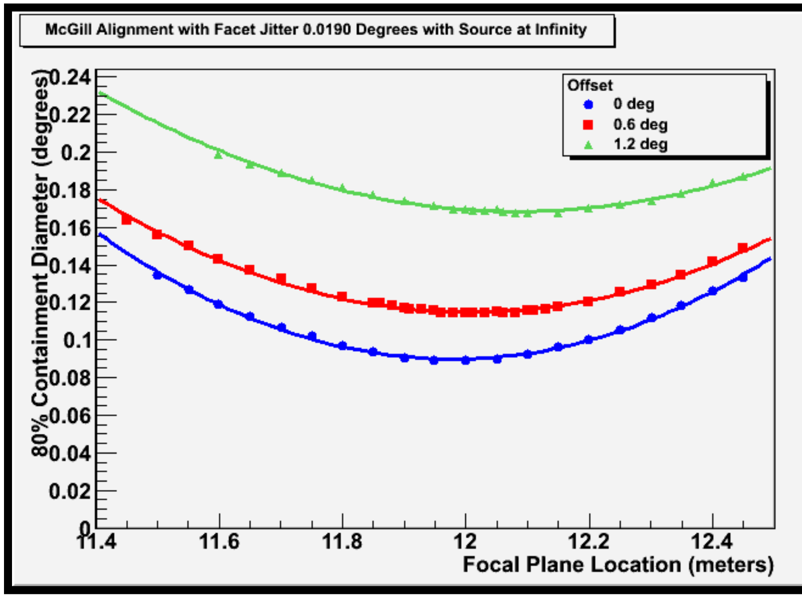


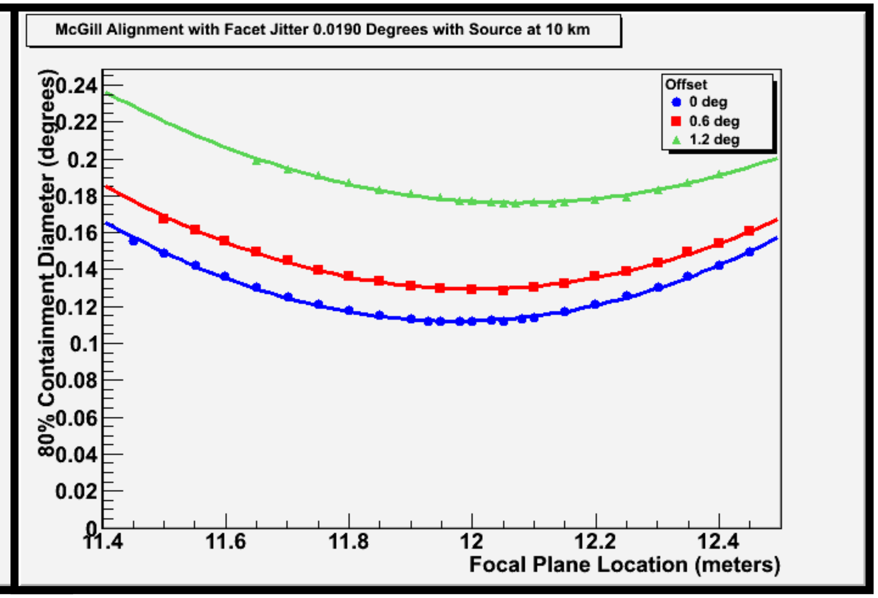
Shows that there is a wide range of focal plane locations that yield results of about the same caliber.



Shows the same thing is true with the source at 10 km instead of infinity.

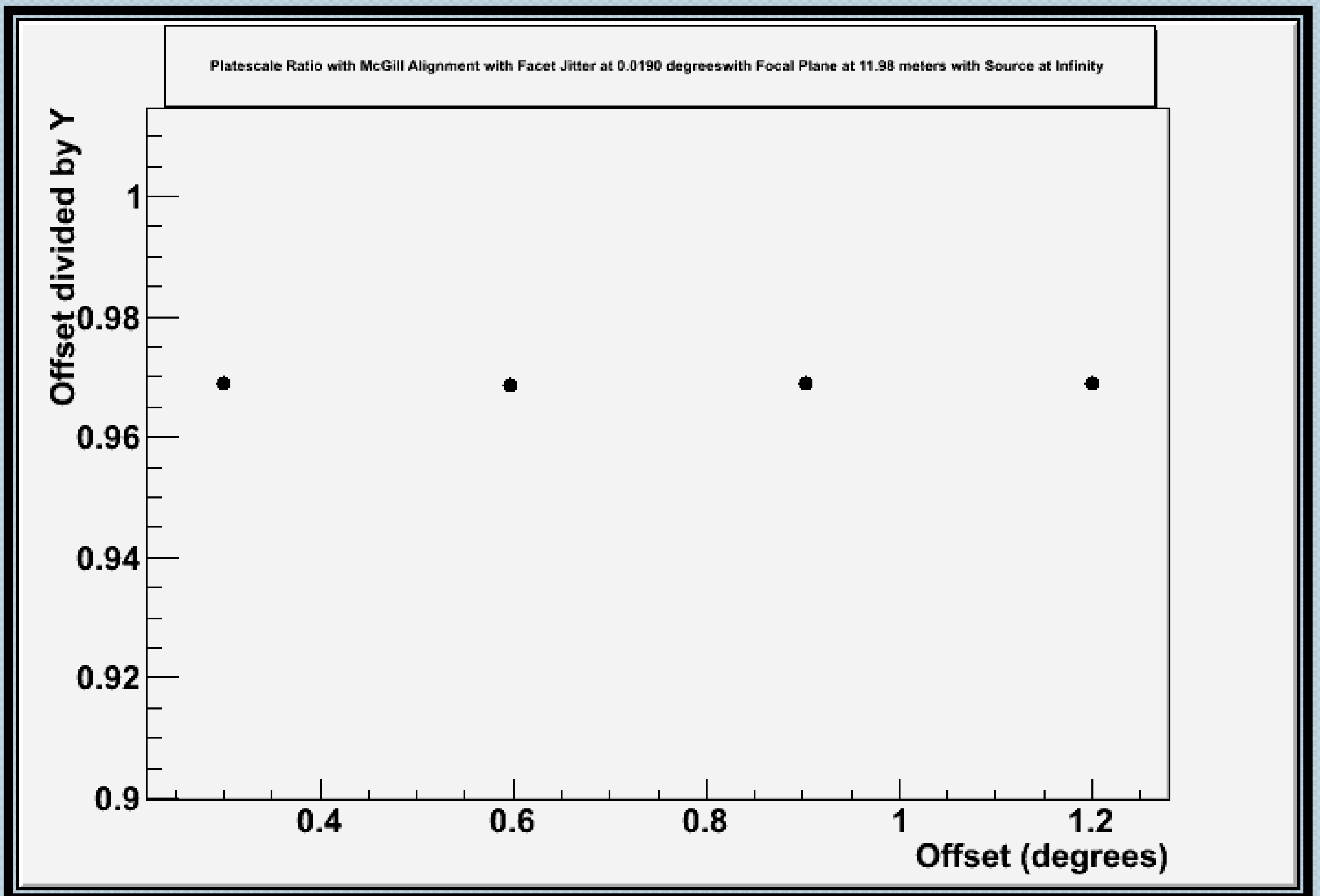
How do they compare?





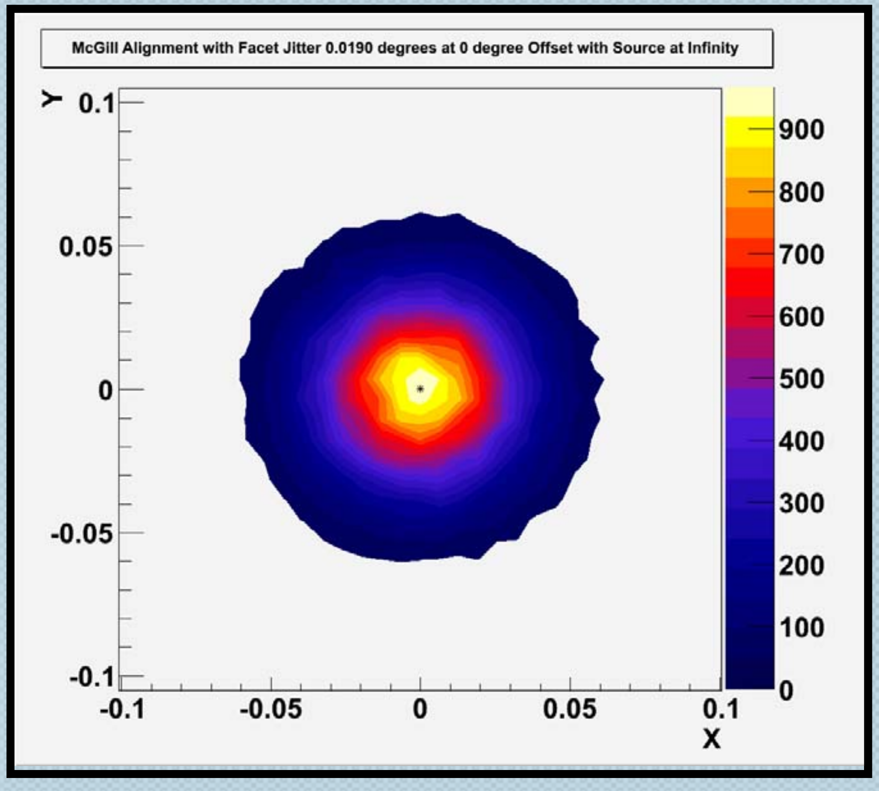
The graphs only differ by about 0.02 degrees in containment. From these graphs we can also see that the minimum is about 11.98 meters.

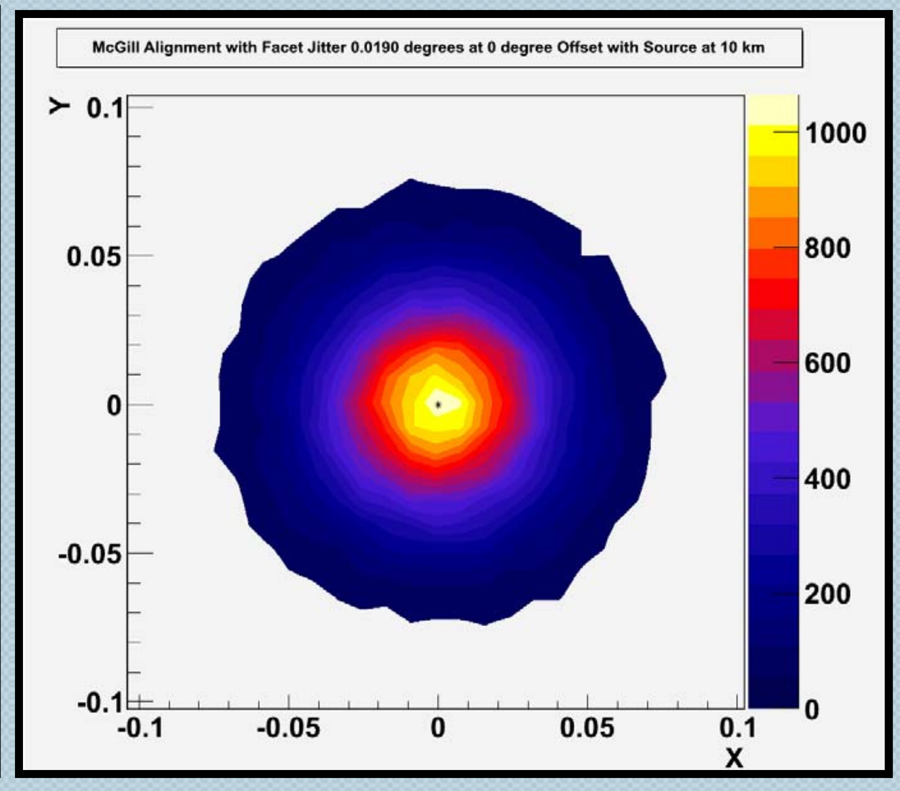
Holds for the source at infinity and 10 km.



Source at Infinity

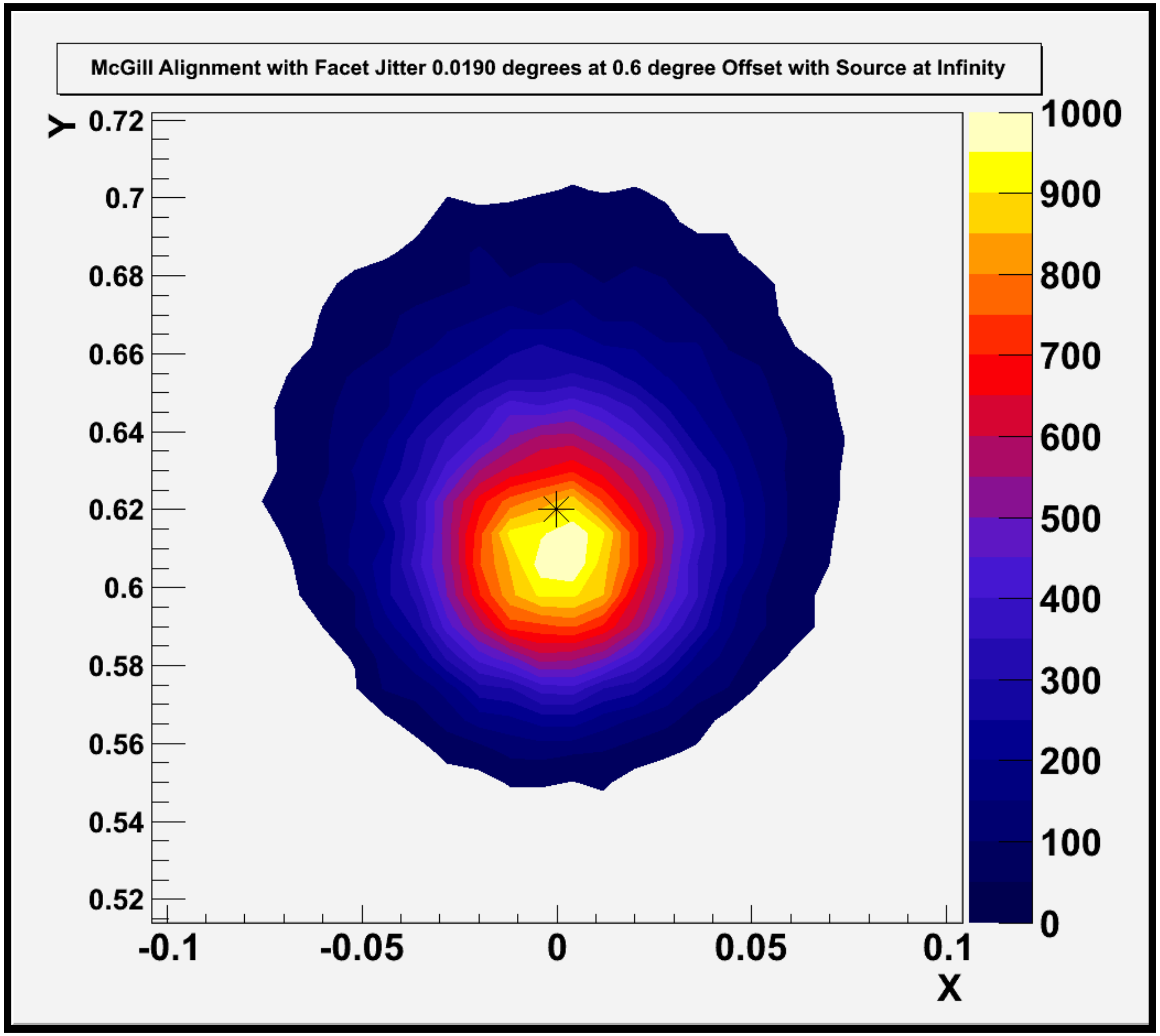
Source at 10 kilometers



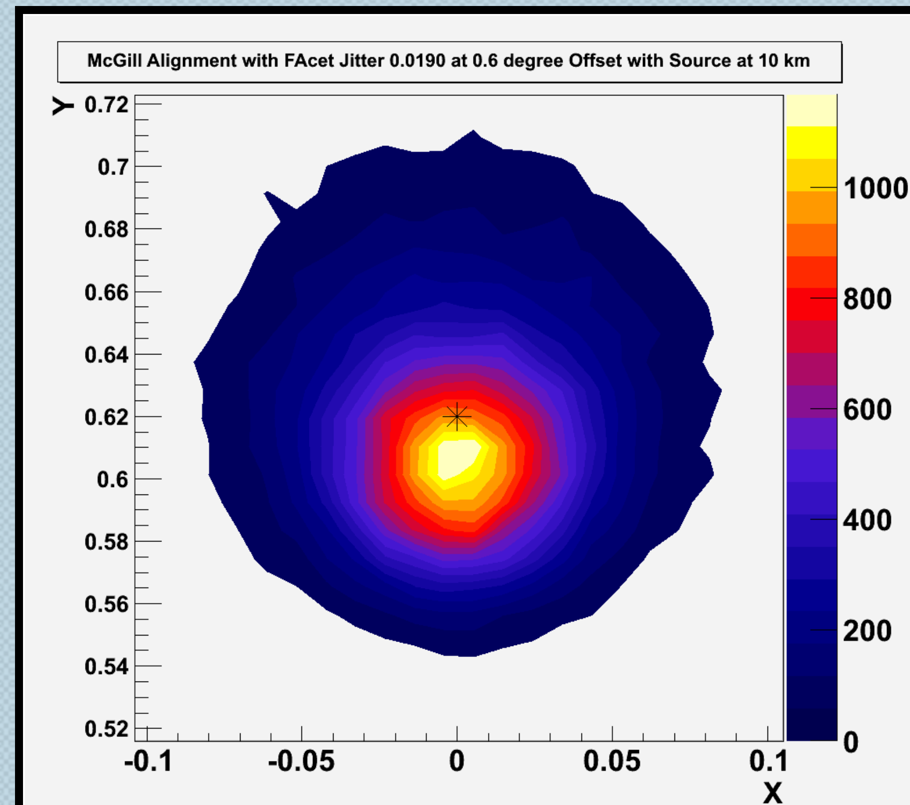


0.0 degree Offset Comparison

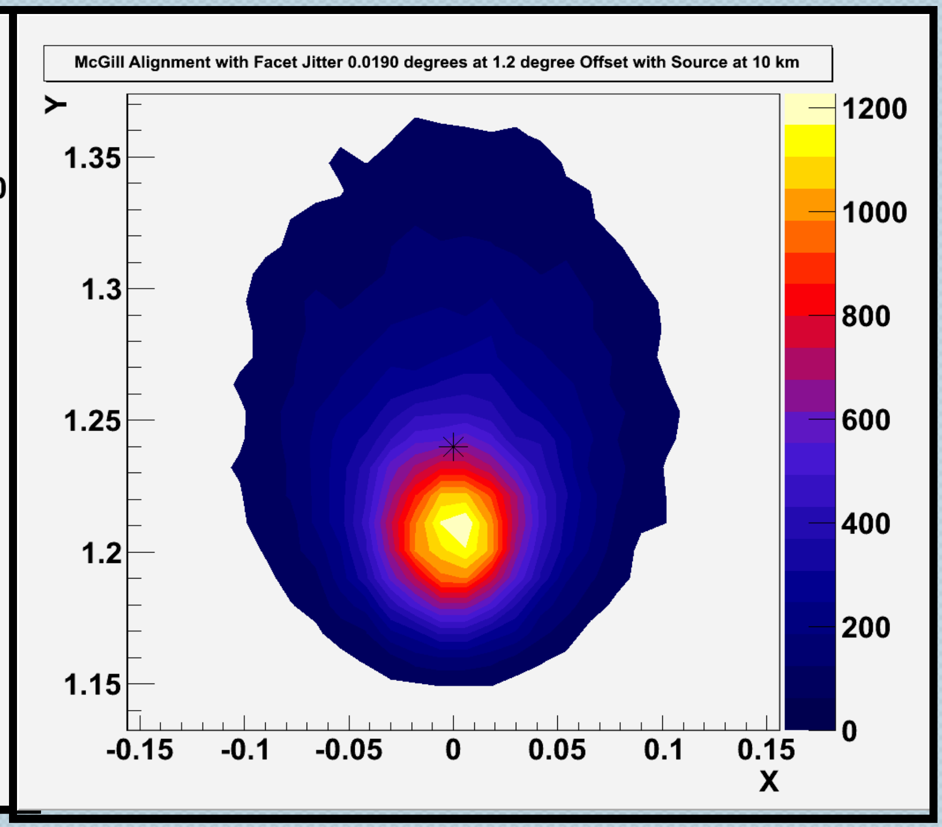
Center of Mass location



0.6 Degree Offset



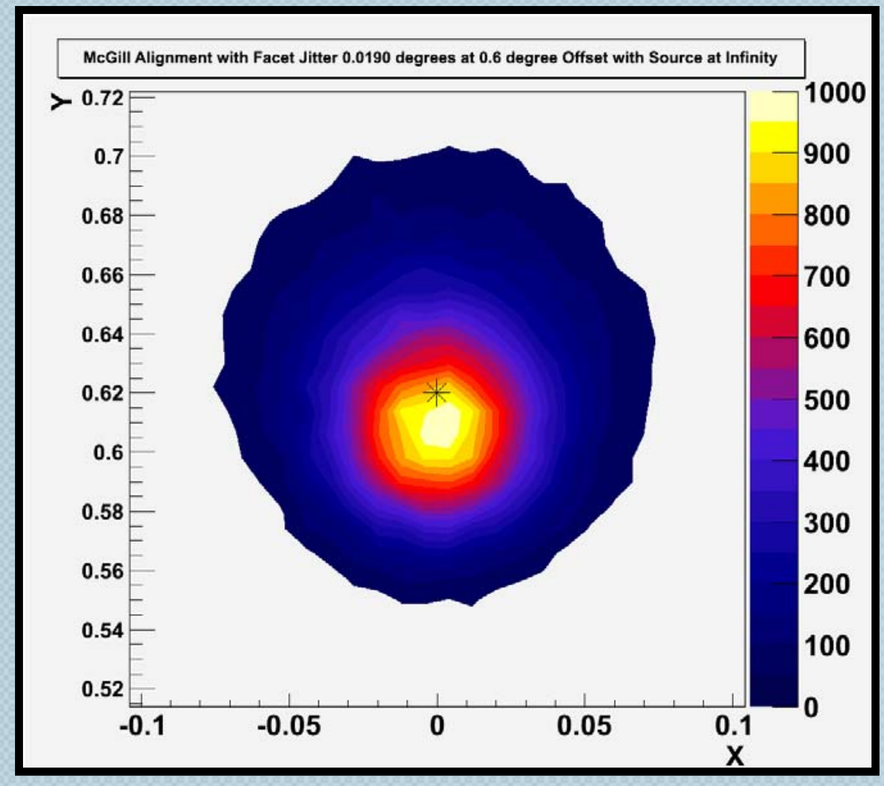
1.2 Degree Offset

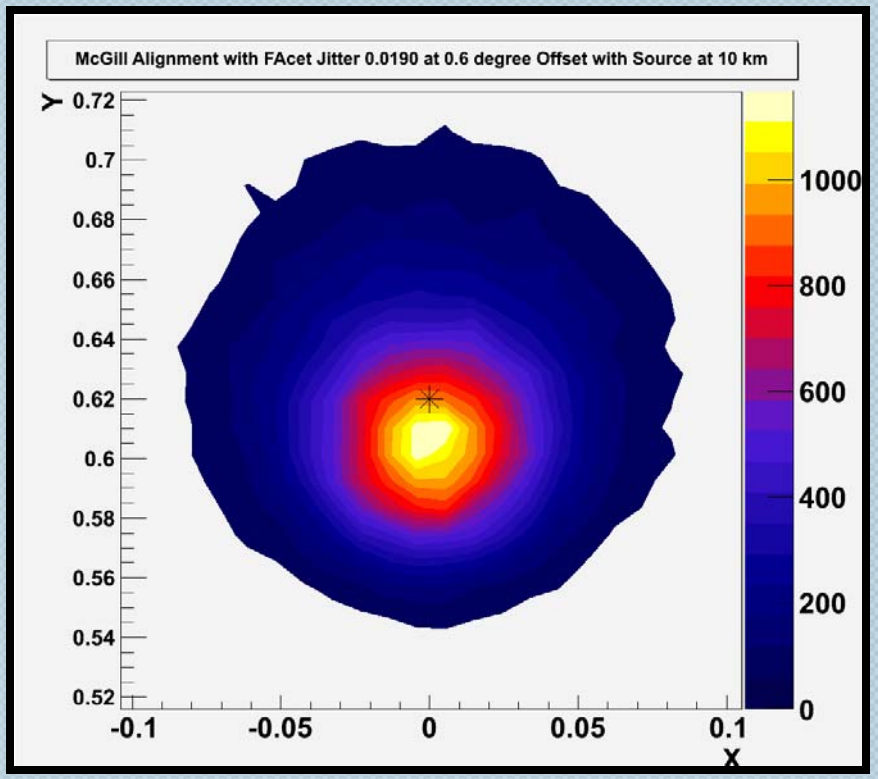


Point spread function comparison at 10 km

Source at Infinity

Source at 10 kilometers

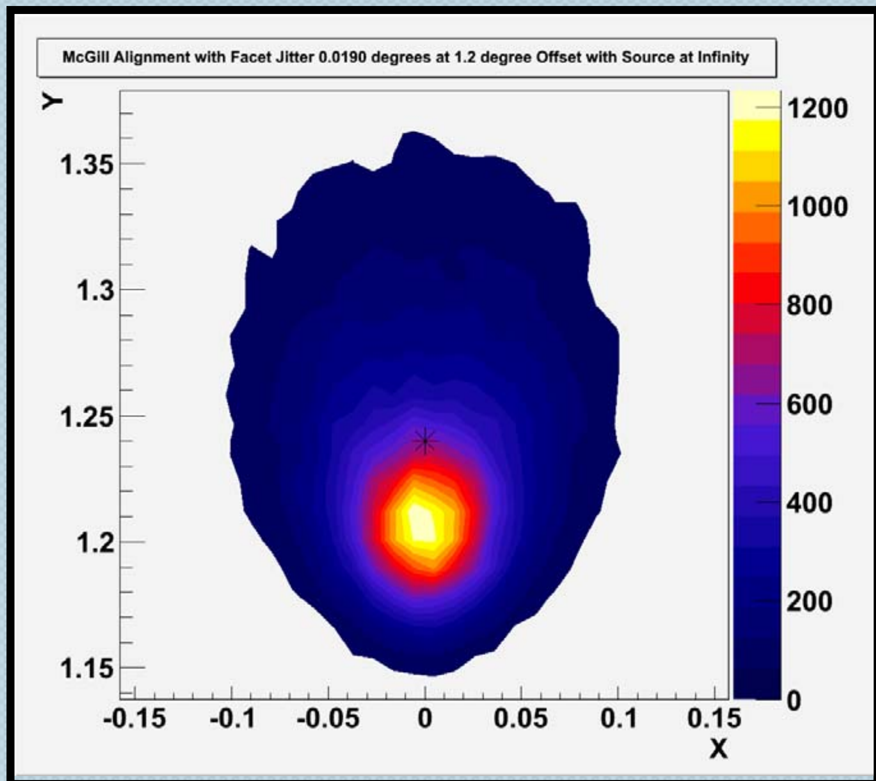


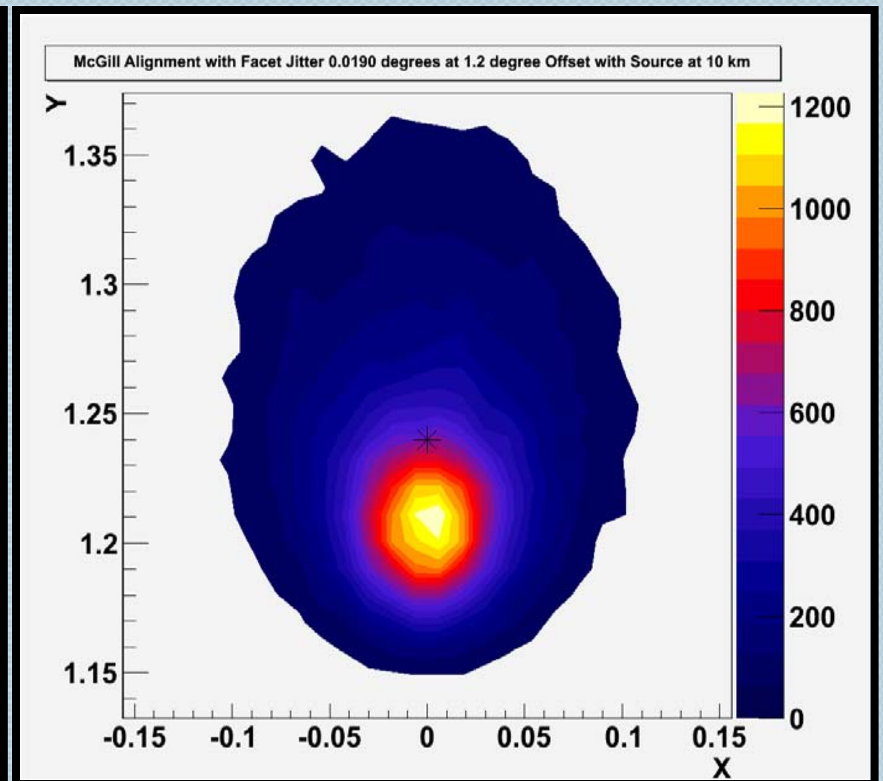


0.6 degree Offset Comparison

Source at Infinity

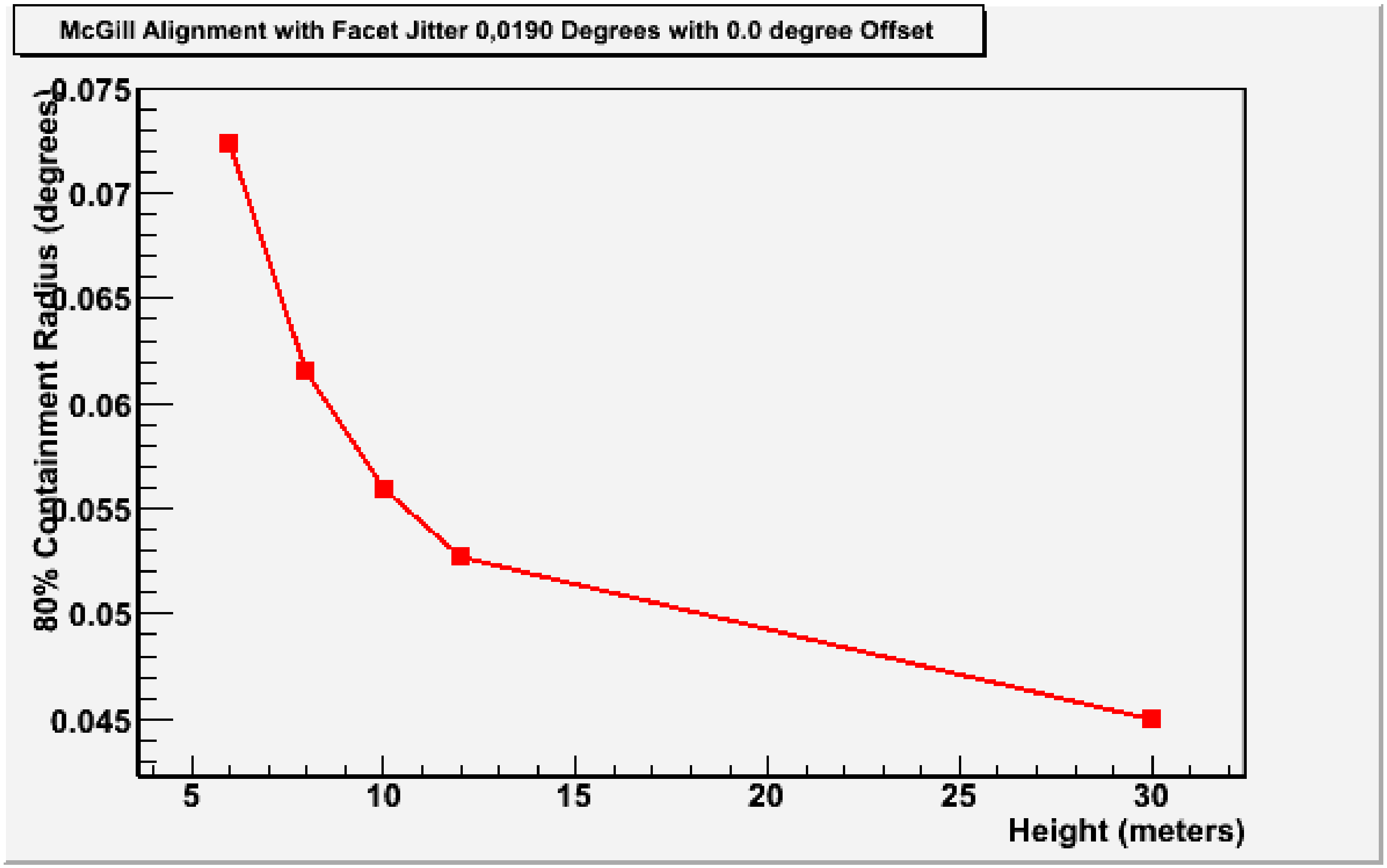
Source at 10 kilometers



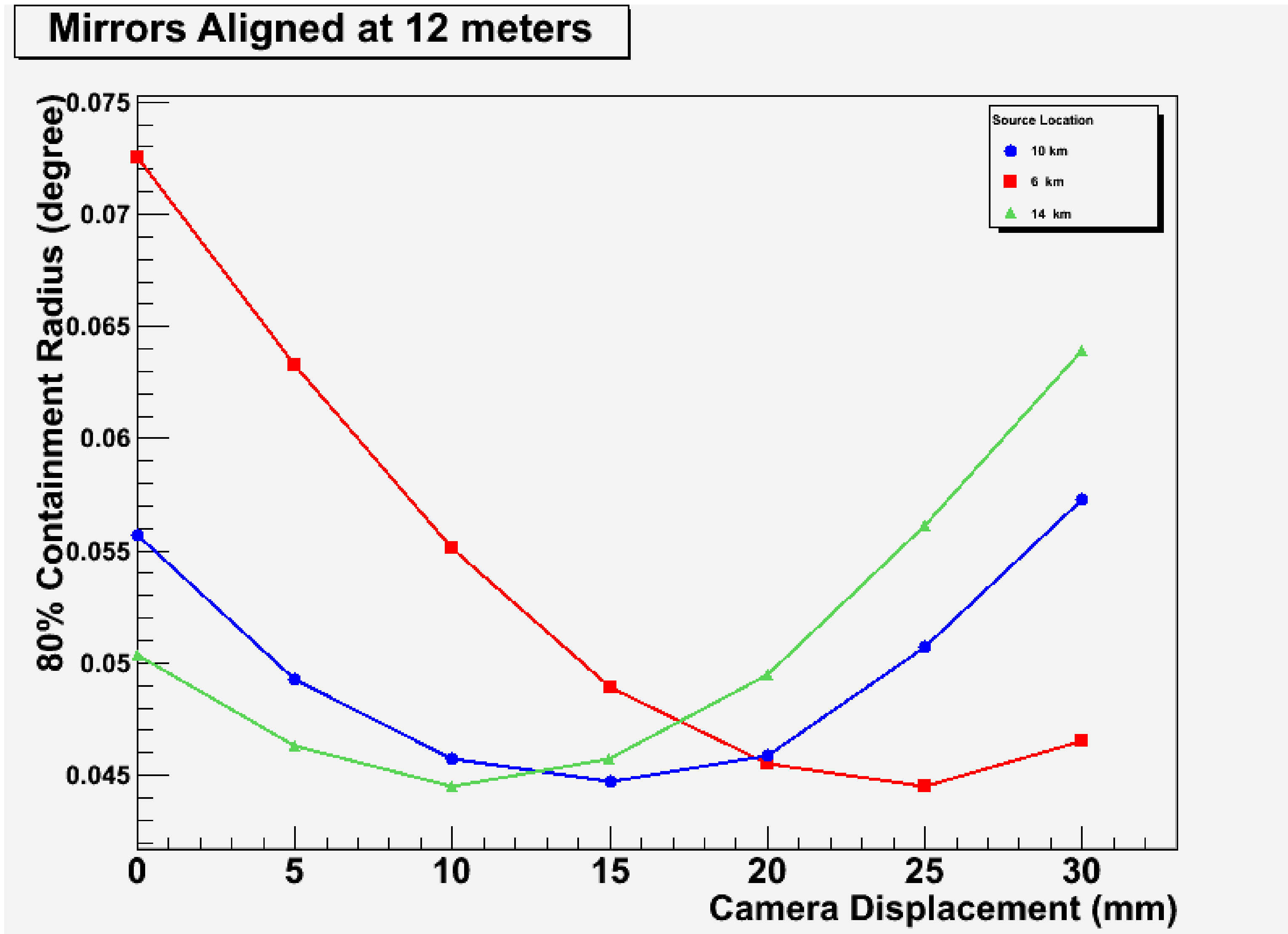


1.2 degree Offset Comparison

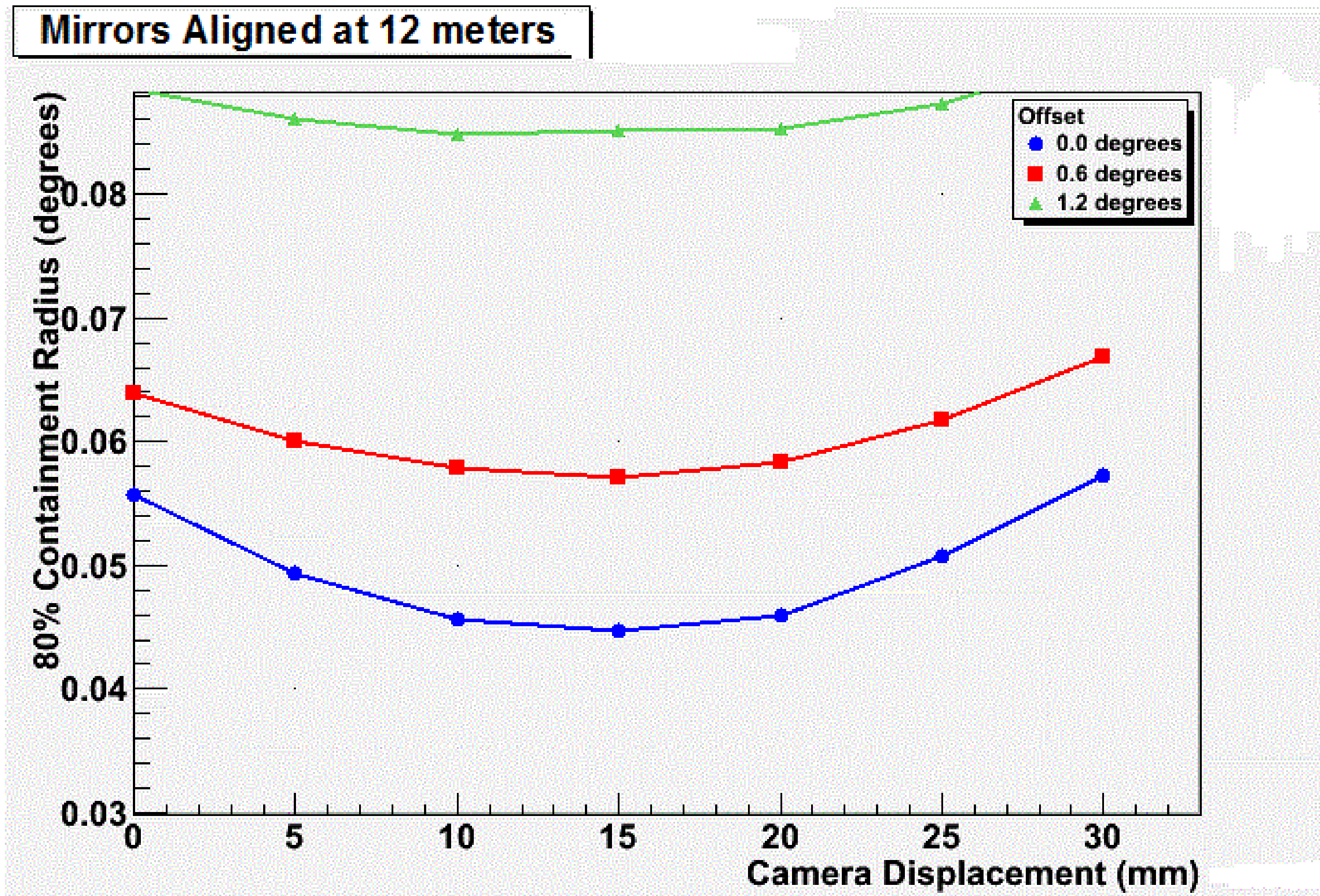
Star at normal position. In agreement with J. Grube.



For the source at 6, 10, and 14 km, the minimum is between 10 and 20 mm displacement.



The source is at 10 km and has a changing offset which has its minimum at ~15 mm displacement. The minimum is close to 0.045 degrees.



Conclusion

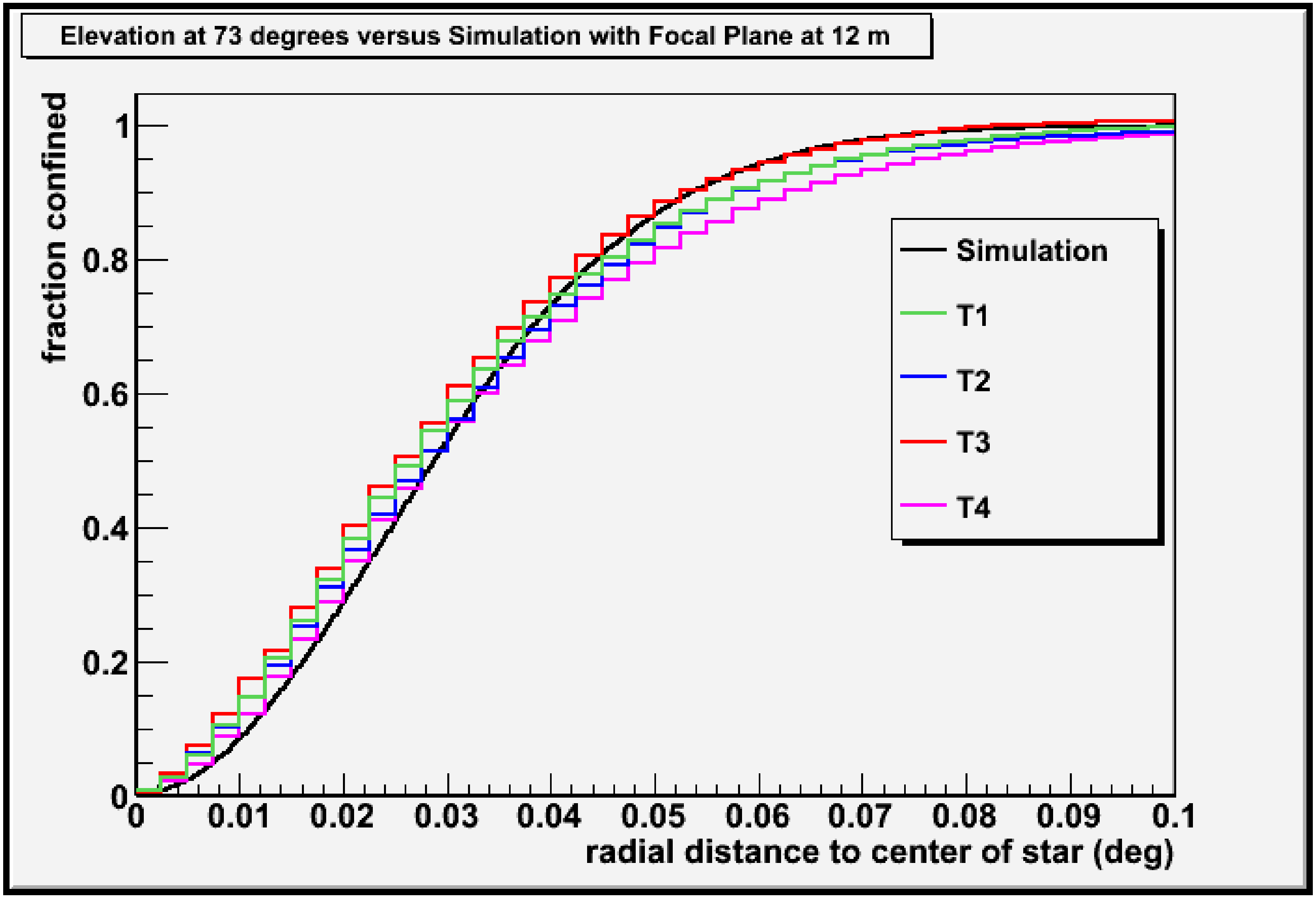
- The data shows that moving the source to 10 kilometers and the camera back by 15 millimeters produces almost the same result as having the source at infinity and the camera at exactly 12 meters.

What's next?

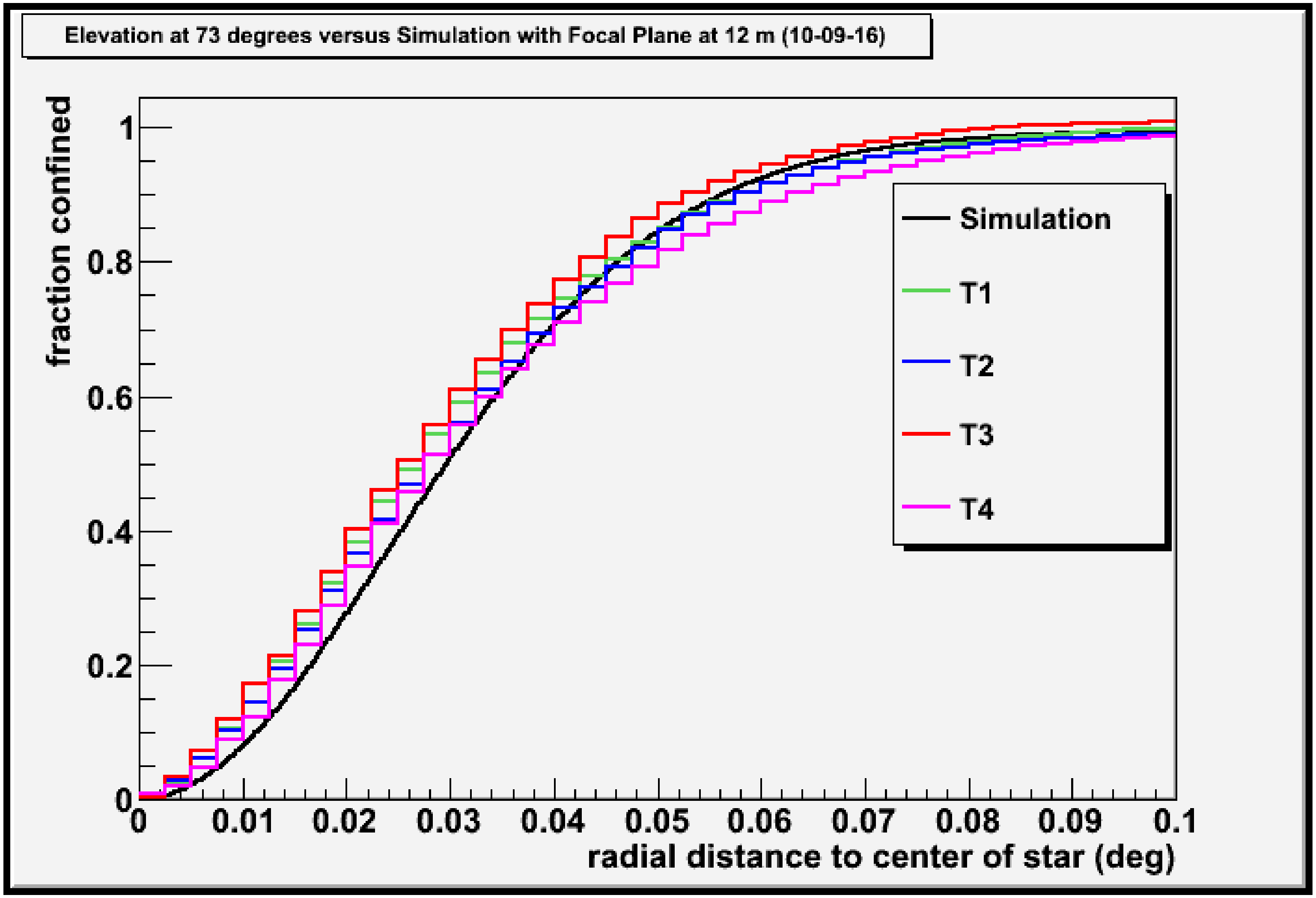
- Further tests to optimize the telescopes capabilities.
  - Add code to place facets instead of randomly generating them
  - Finding shower maximum location
- Gamma Ray Shower Simulations (if there is time)

COMPARING SIMULATIONS TO REAL DATA

Hillas Method

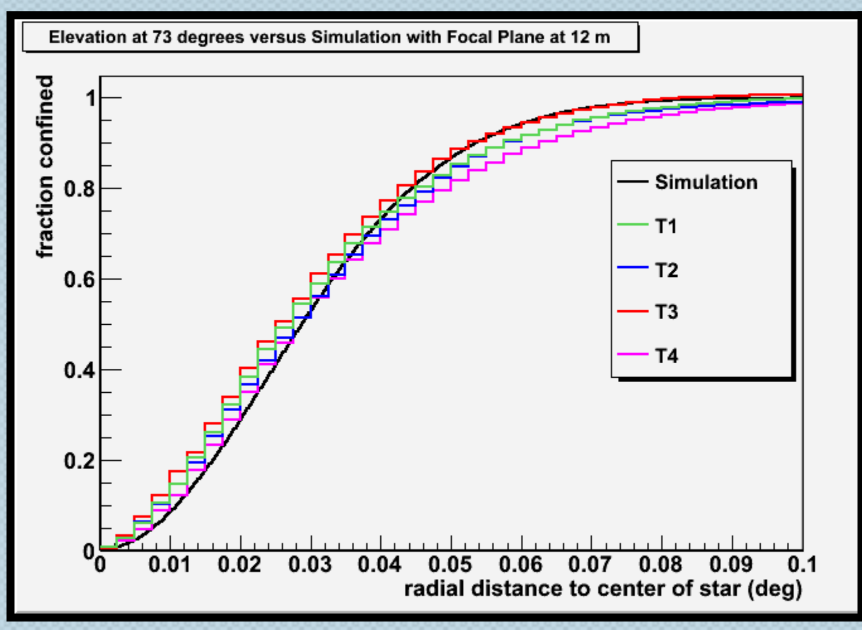


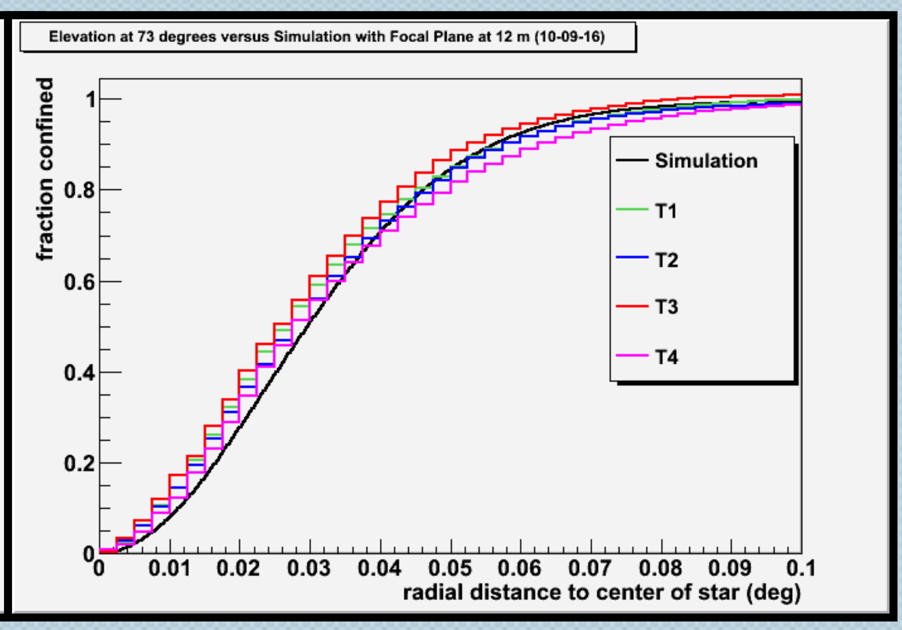
With VeritasFacetLocations.txt



Hillas Method

Using actual facet locations





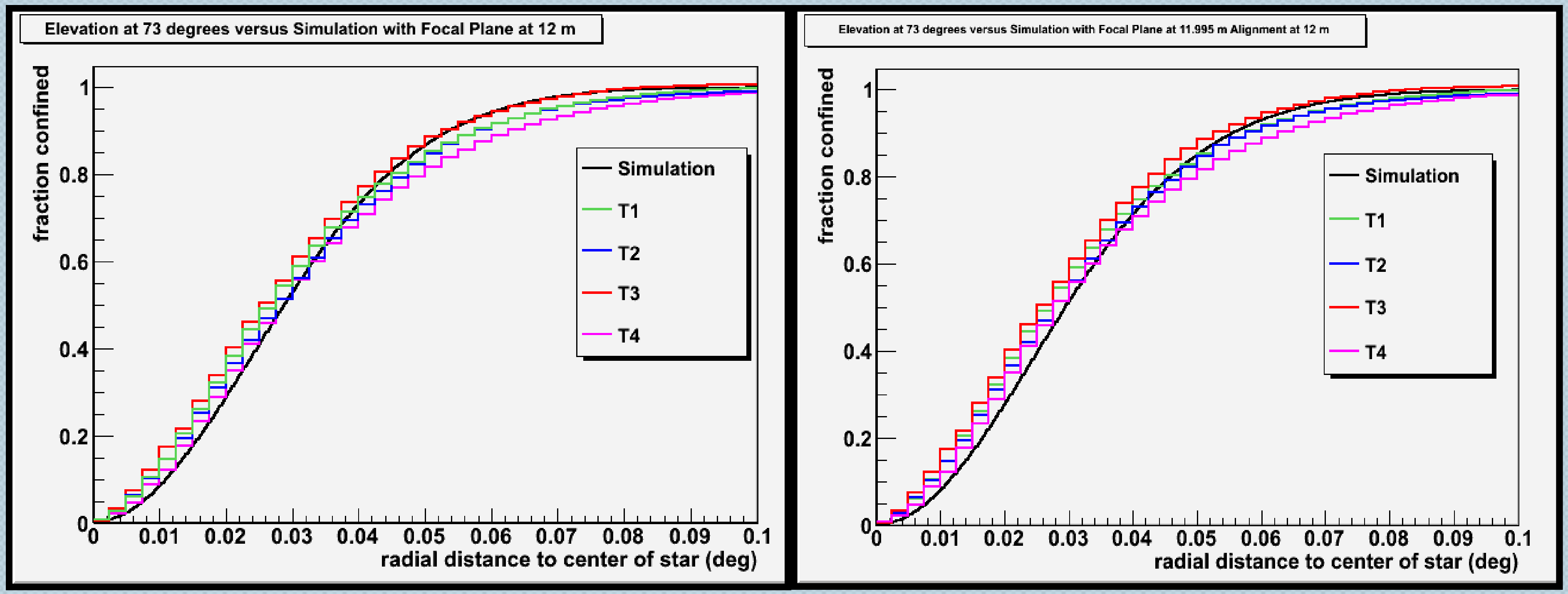
The actual facet locations create about the same match for the beginning of the curve but a better fit with the top curve.

Is there a way to change the simulation to better match the observed data?

Original simulation
Focal Plane at 12 m

Simulation with Focal Plane at 11.995 meters or 12.005 meters

Hillas Method

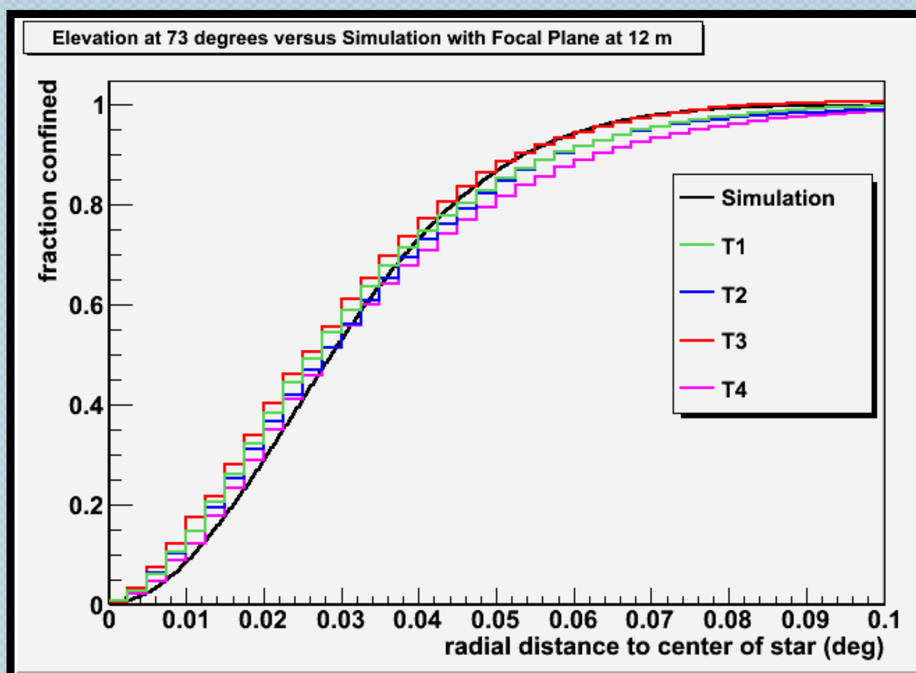


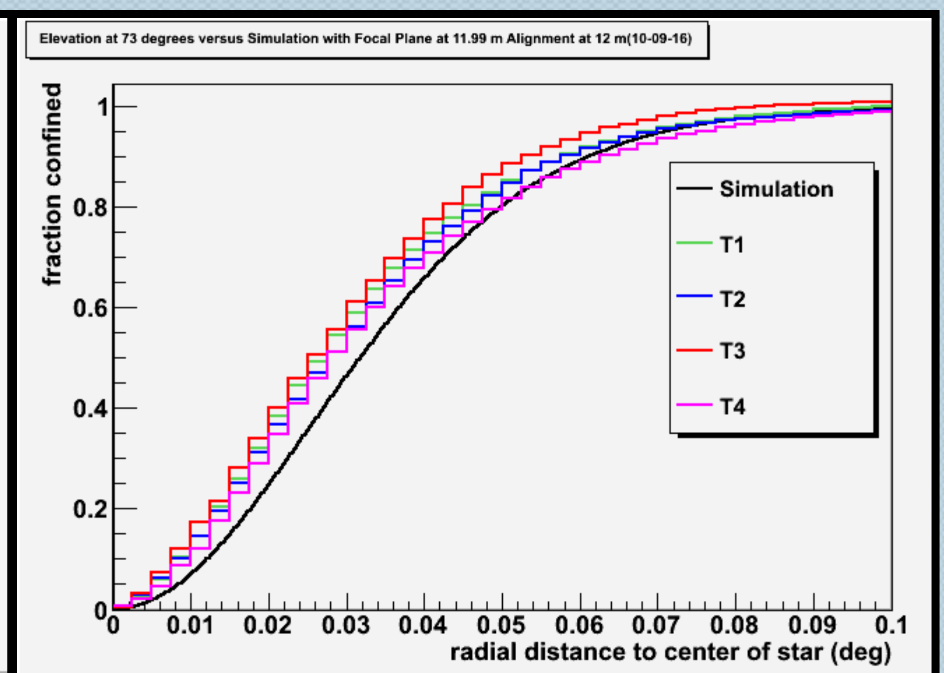
The fit with the simulation remained constant for about 5 mm up or down from the original focal plane location.

Original simulation at 12 meters

Simulation at 11.99 meters or 12.01 meters.

Hillas Method

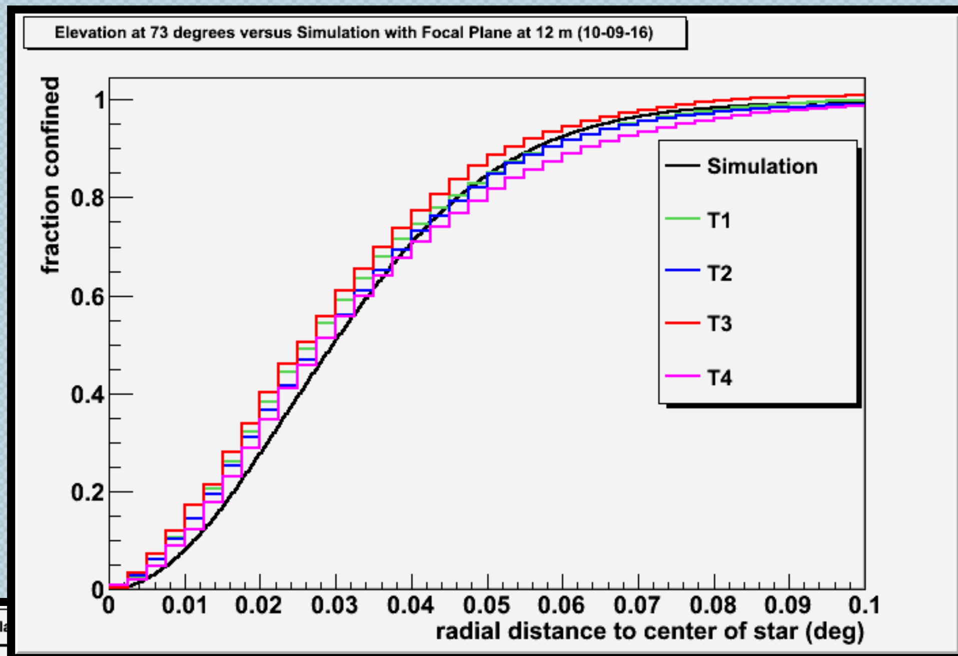




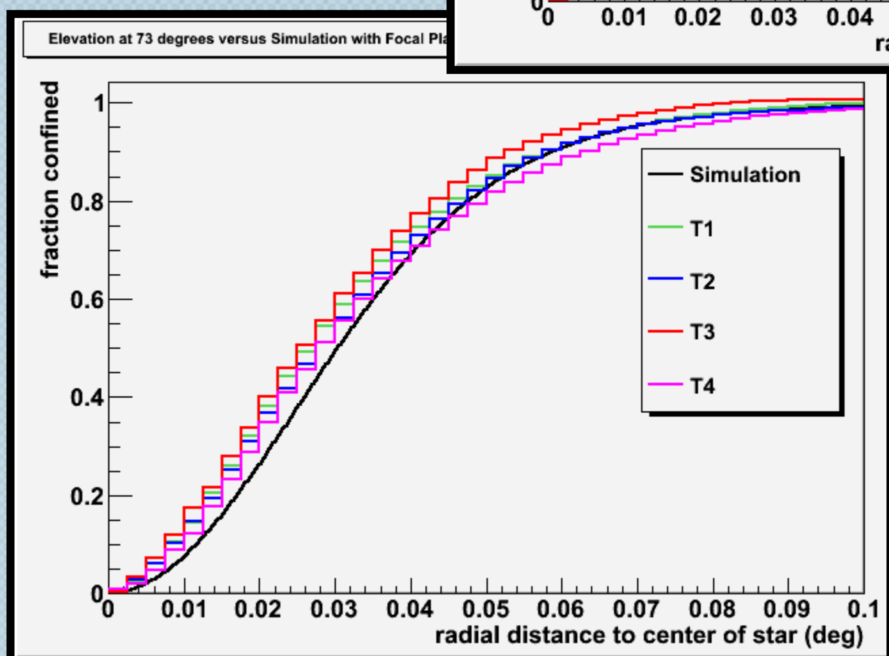
However, it was an acceptable fit for another 5 mm. So there is about a 2 cm range that does not matter.

Actual Facet Locations

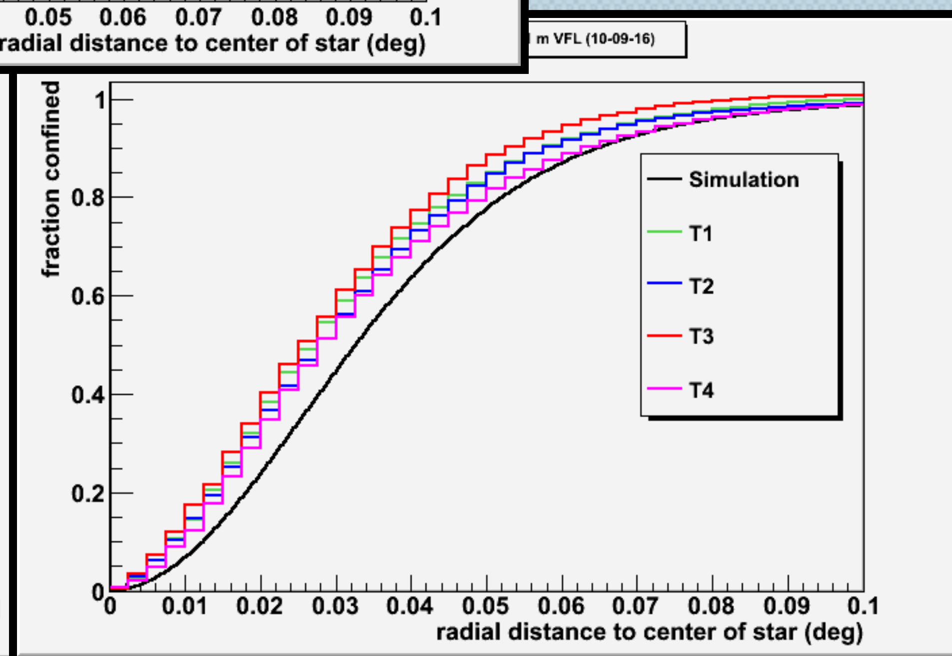
Focal Plane at 12 meters



Focal plane at 12.005 m



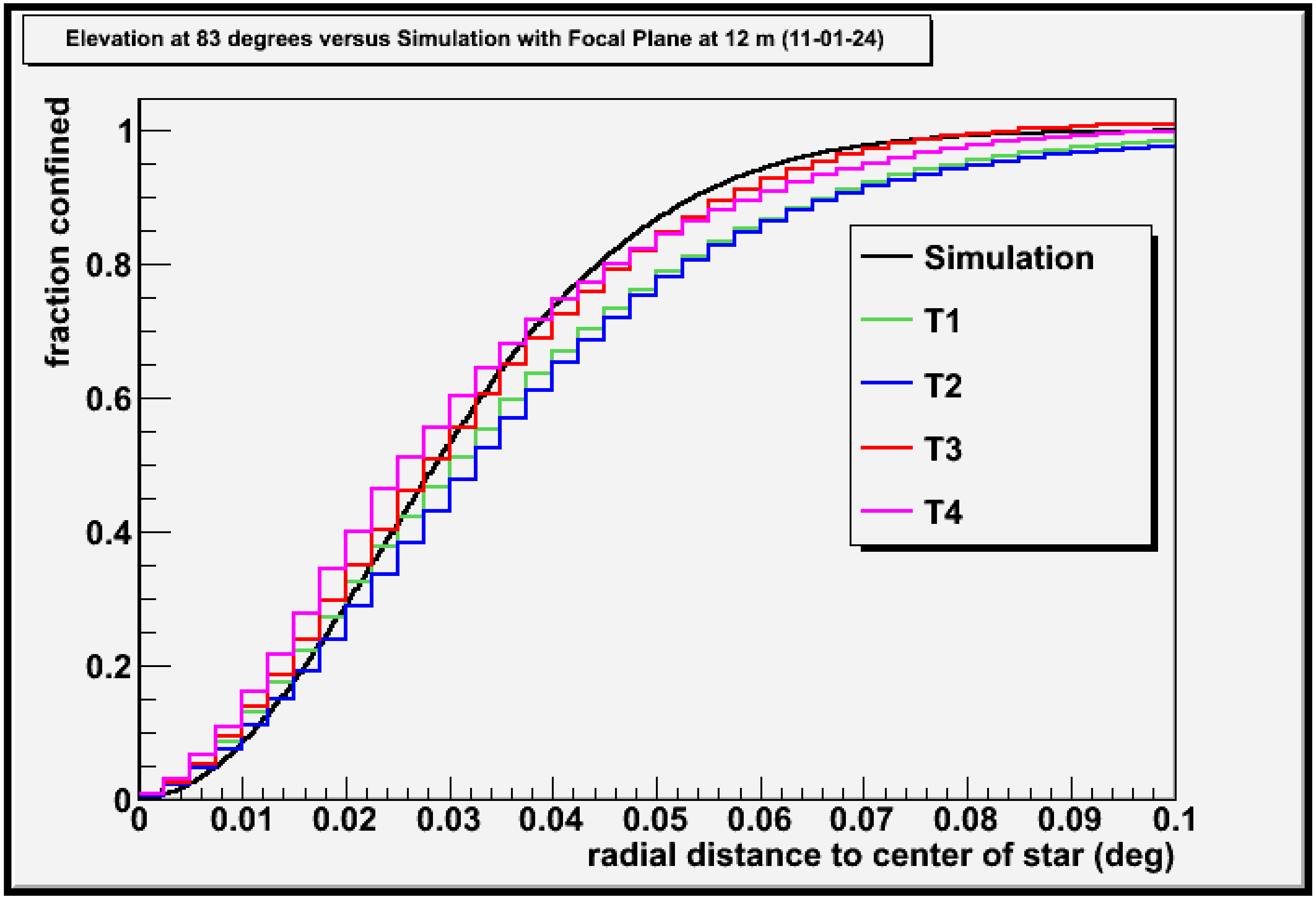
Focal Plane at 12.01 m



Result

- Both methods have a range of fits that are very similar. However, the best fit uses the actual facet locations at a focal plane length of 12 meters

The simulation does not fit as well on the top curve for elevations closer to zenith.

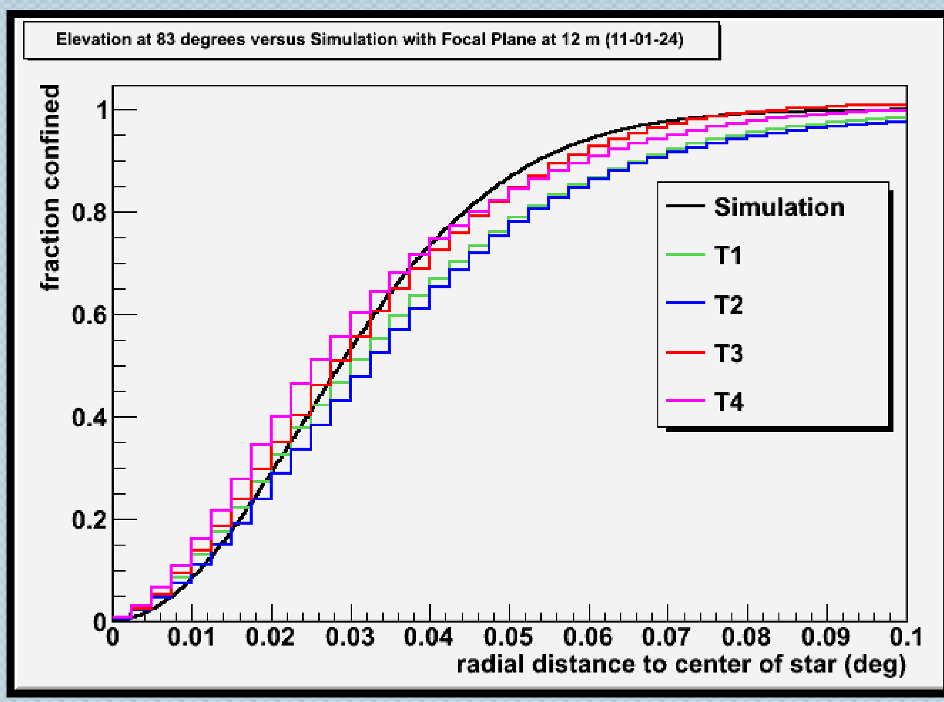


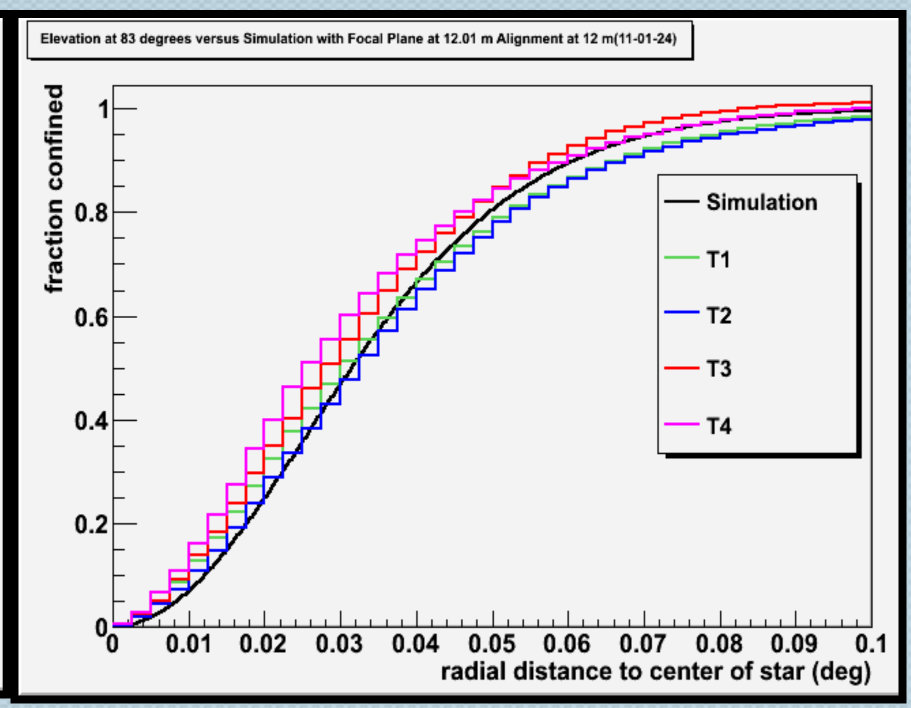
Hillas Method

Original focal plane location.

Focal plane at 11.99 meters or 12.01 meters.

Hillas Method

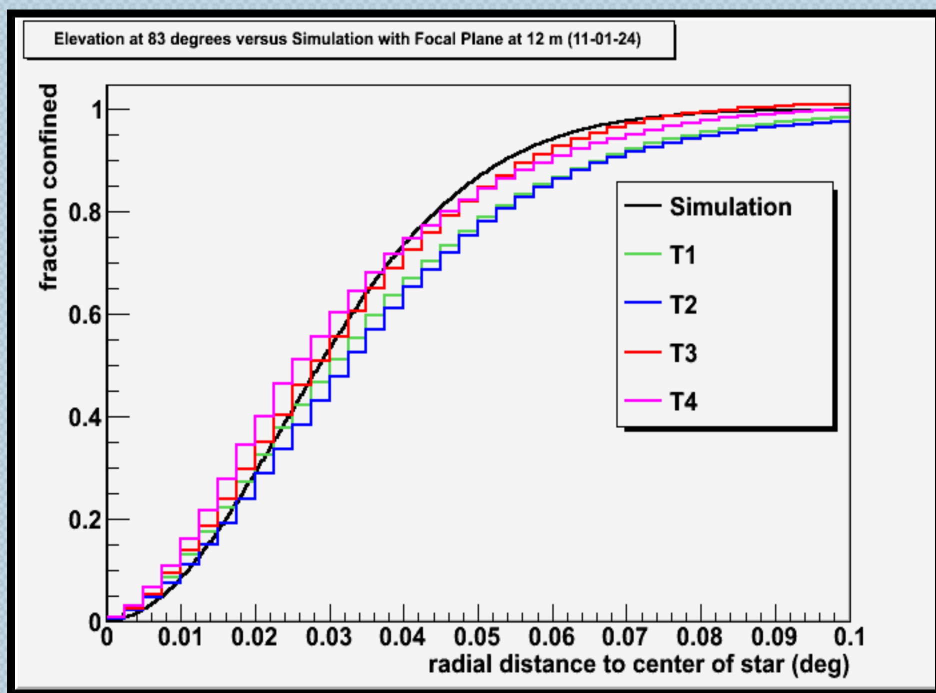


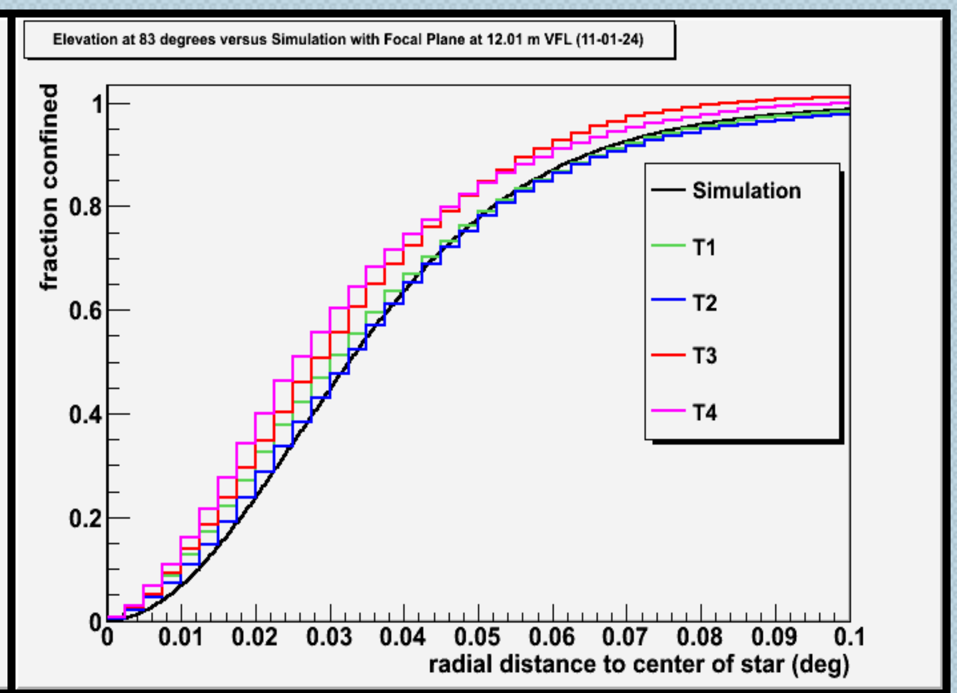


Moving the focal plane by 1 cm creates a fit that is much more accurate.

Focal Plane at 12 meters

Focal Plane at 12.01 meters



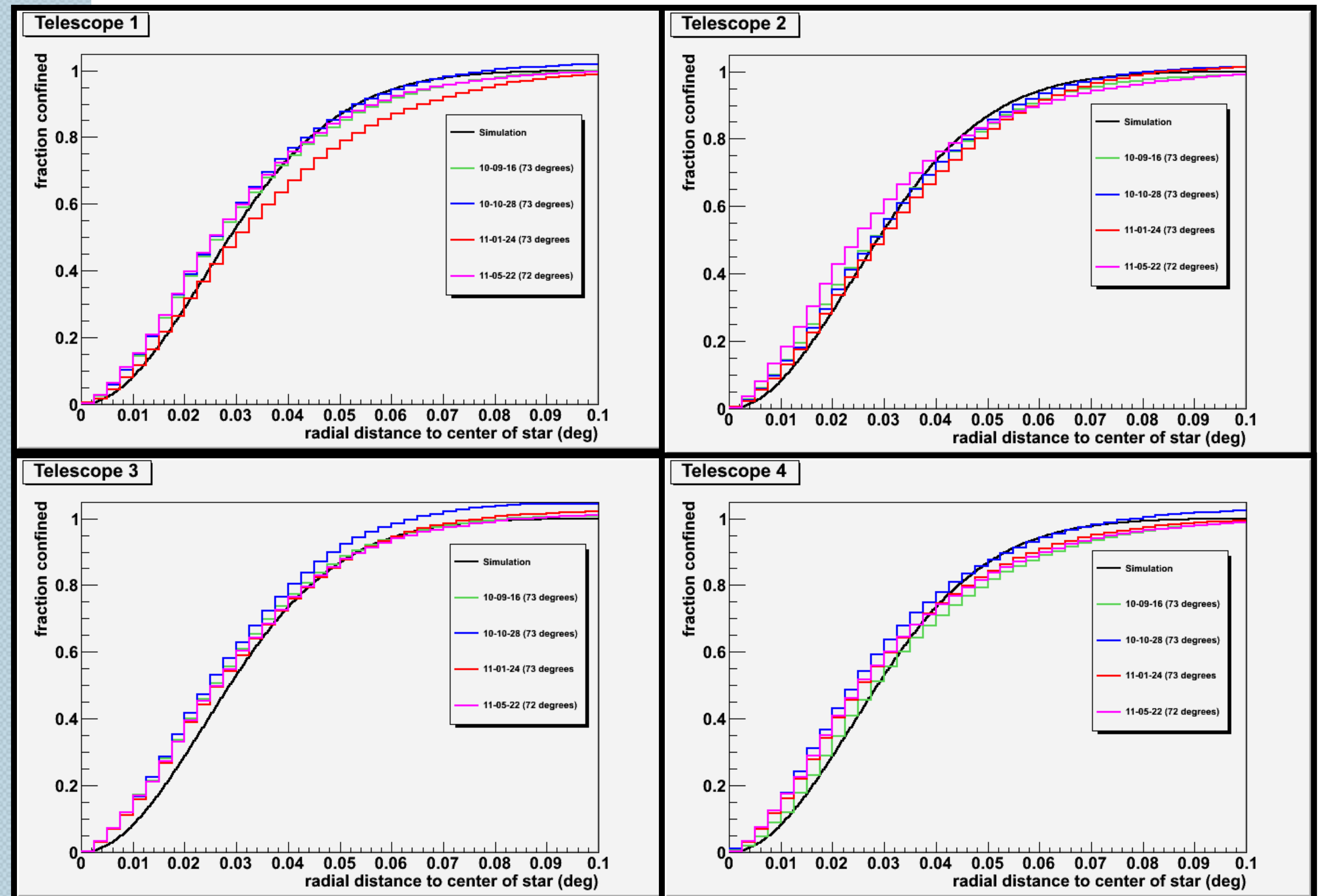


Using actual facet locations we see the fit improves in some areas when the focal plane location is moved by 1 cm

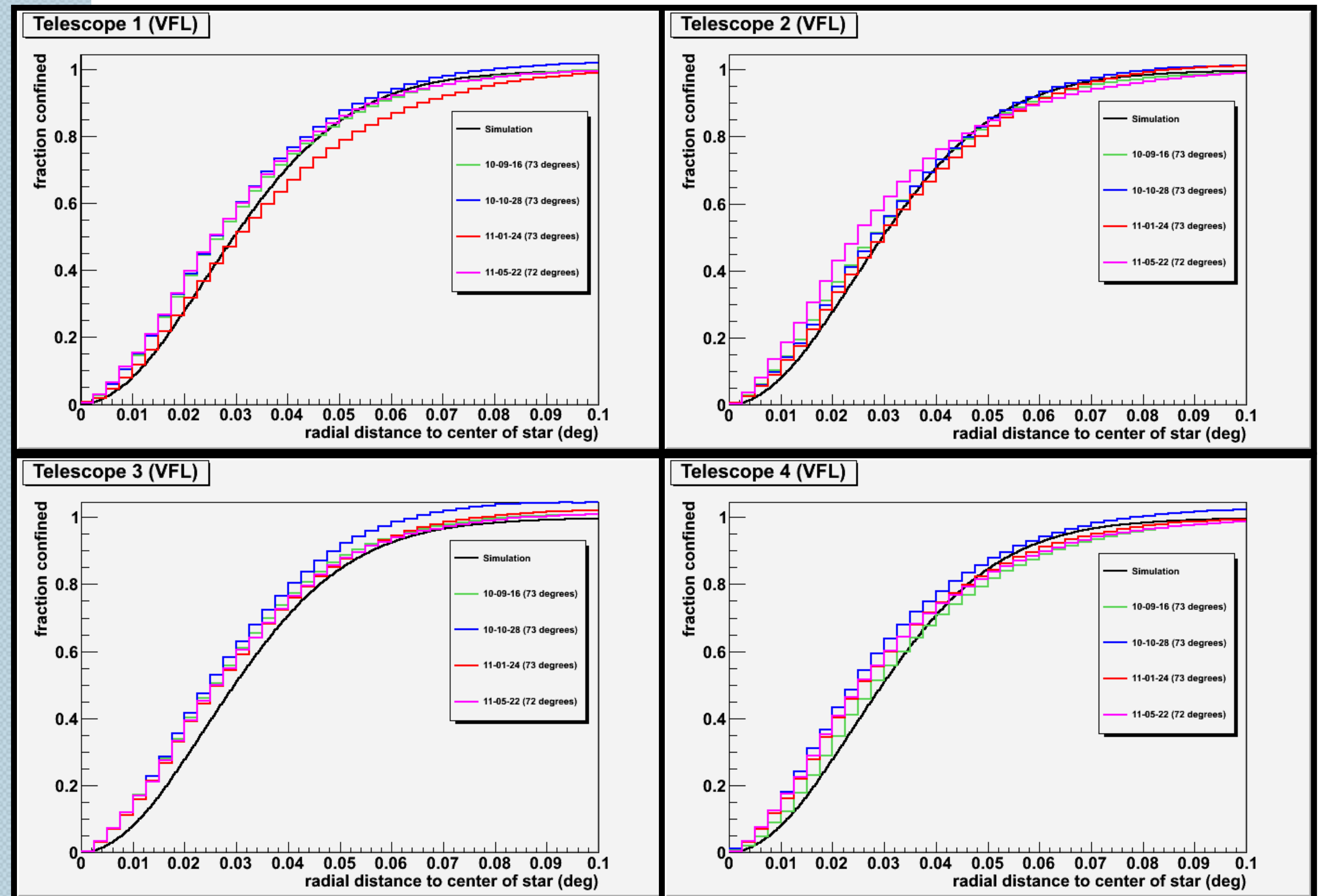
Result

- The original facet locations fit is better than the original Hillas fit, but the Hillas at focal plane location of 12.01 meters is the best fit out of all four graphs.

Hillas Method



Actual Mirror Facets



Conclusion

- Using the actual facet locations will improve the fit opposed to randomly creating them
- In the future
  - Create a second jitter to make our simulations better match the data.