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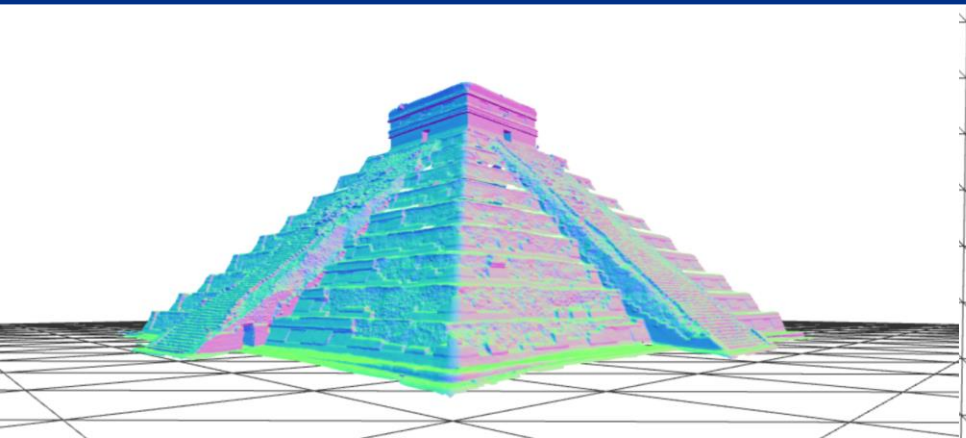
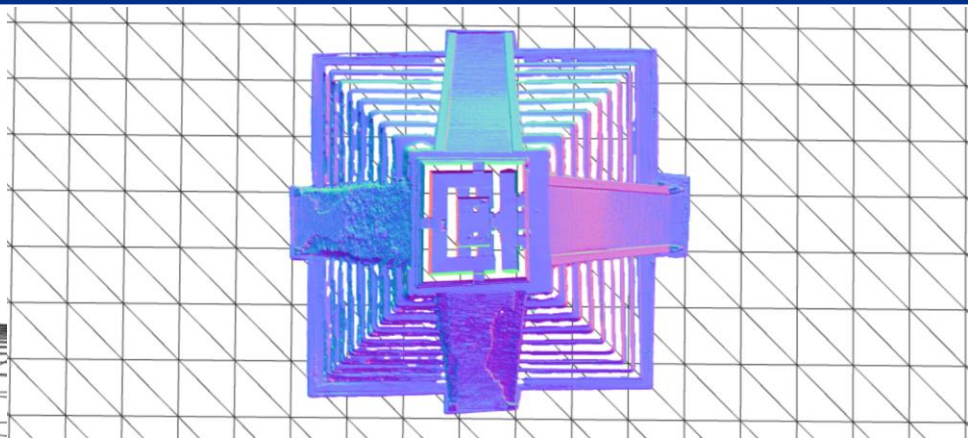
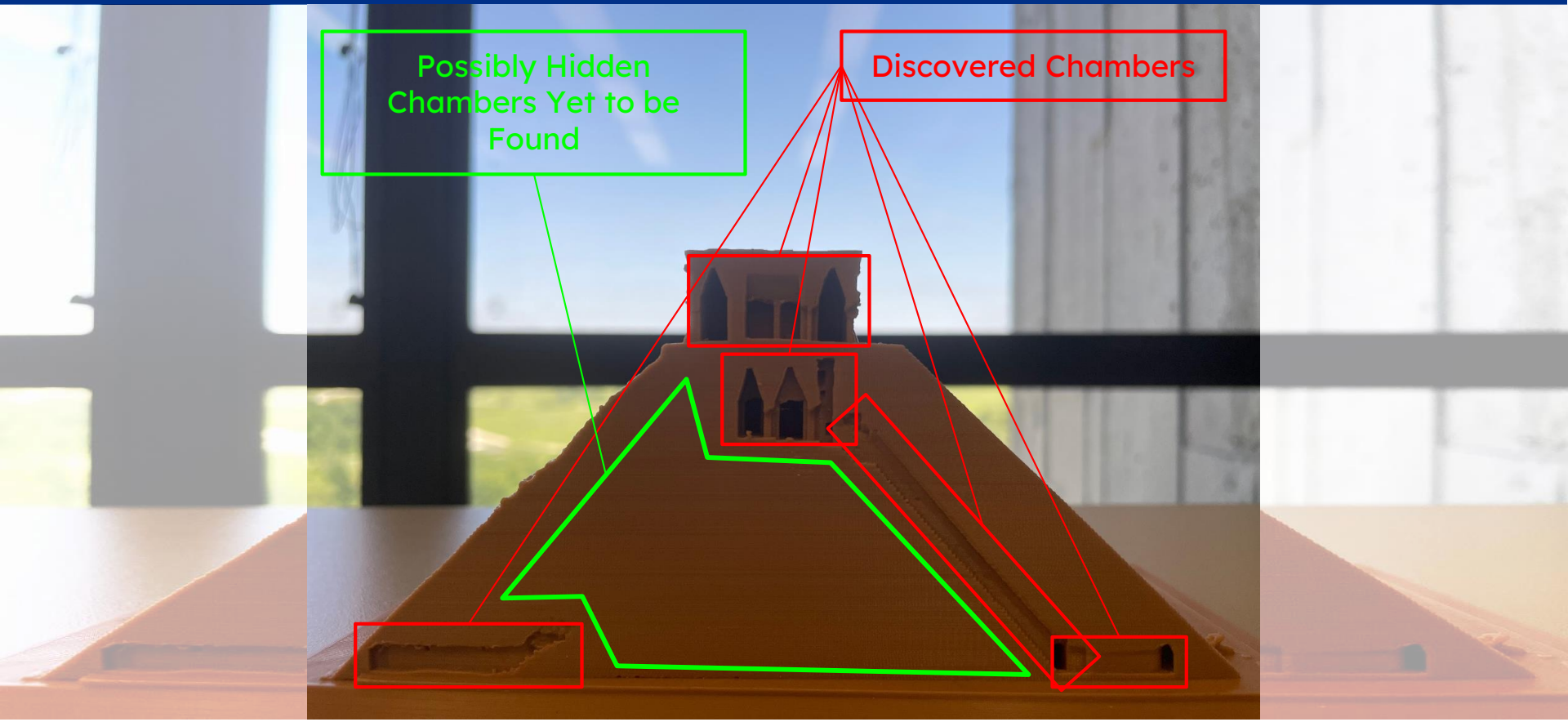
3D Visualization and Analysis of Kukulkan Pyramid Using Muon Tomography



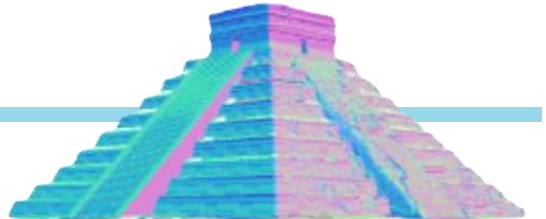


The Structural Layout



Muography sensor will search for any hidden chambers in the highlighted green area.

Due to the nature of possibly stacking chambers in this fashion, there is a high probability a chamber will be found.



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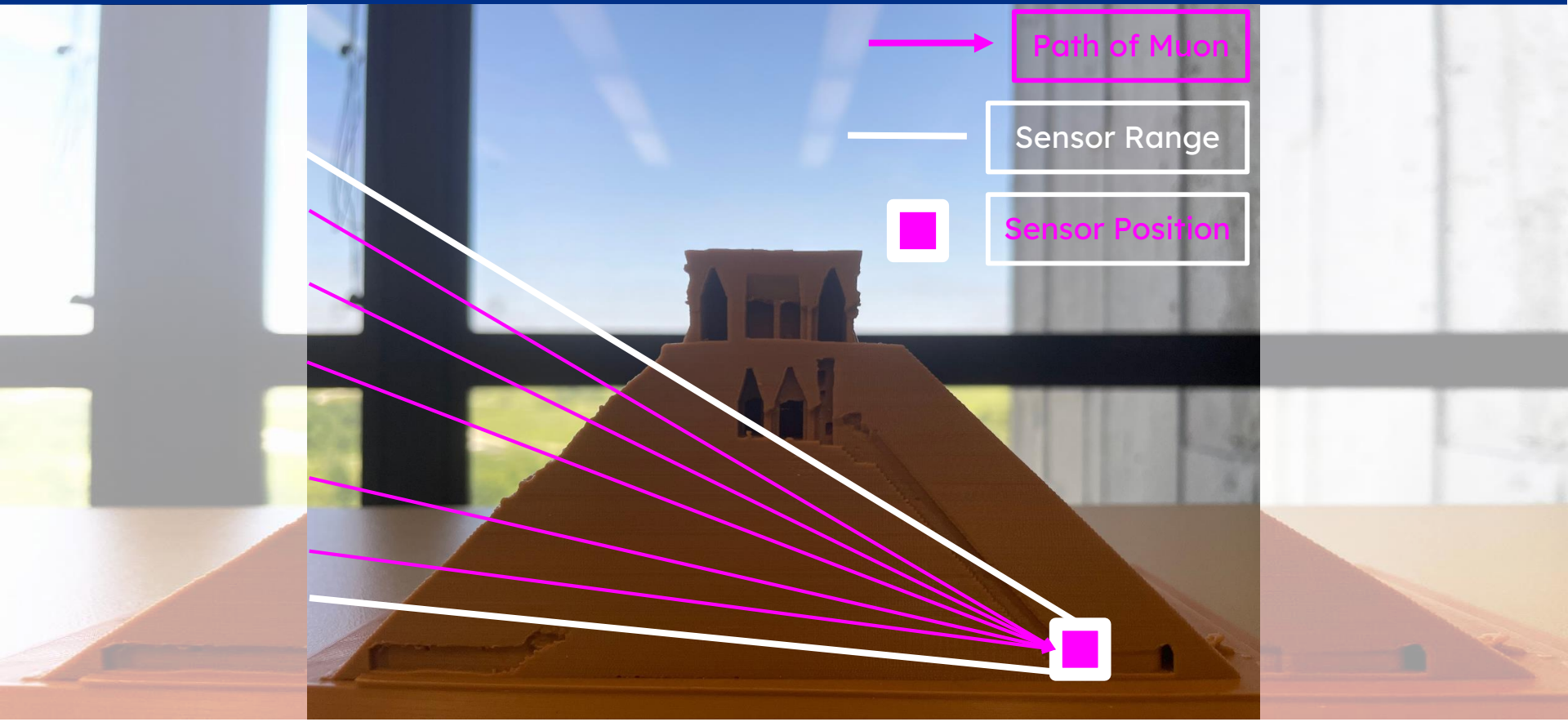
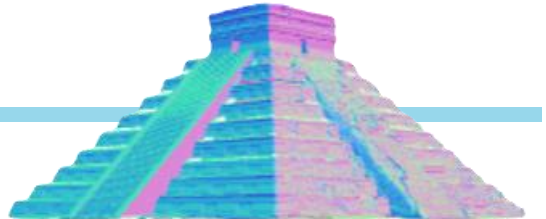
Sensor Placement



Our sensor will be placed near the north tunnel of the pyramid (shown on the right)

Any incoming muons will be collected within its range of acceptance

Another sensor may be placed in the south tunnel



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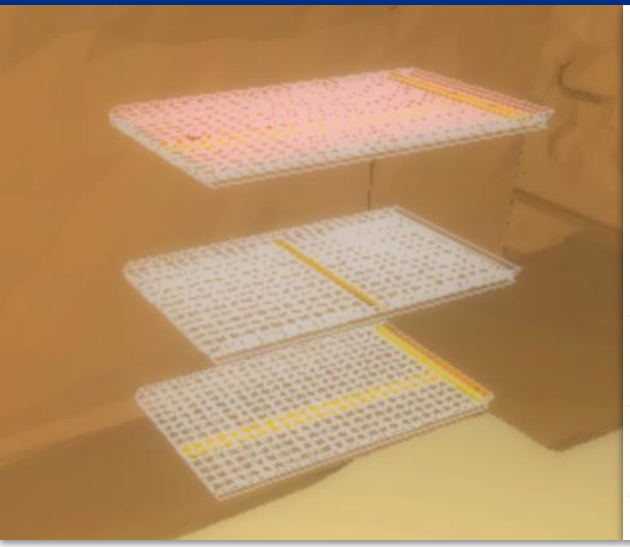
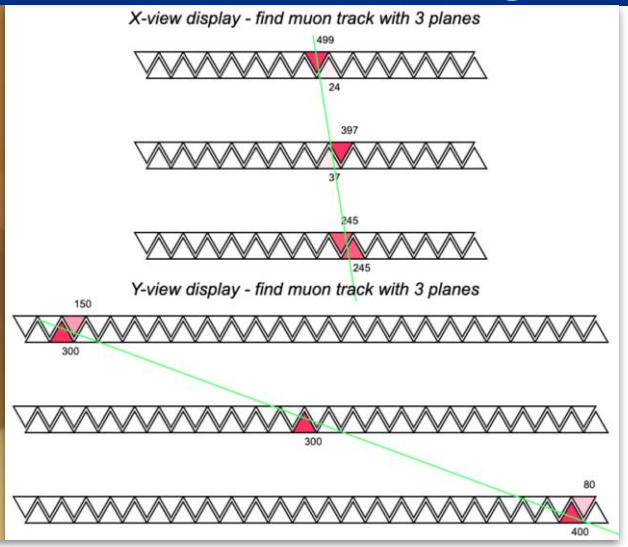
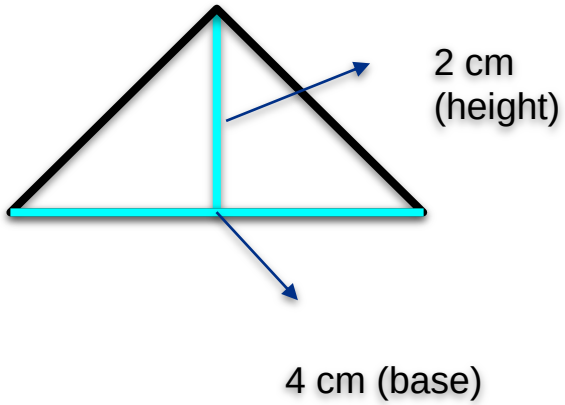
Sensor Design





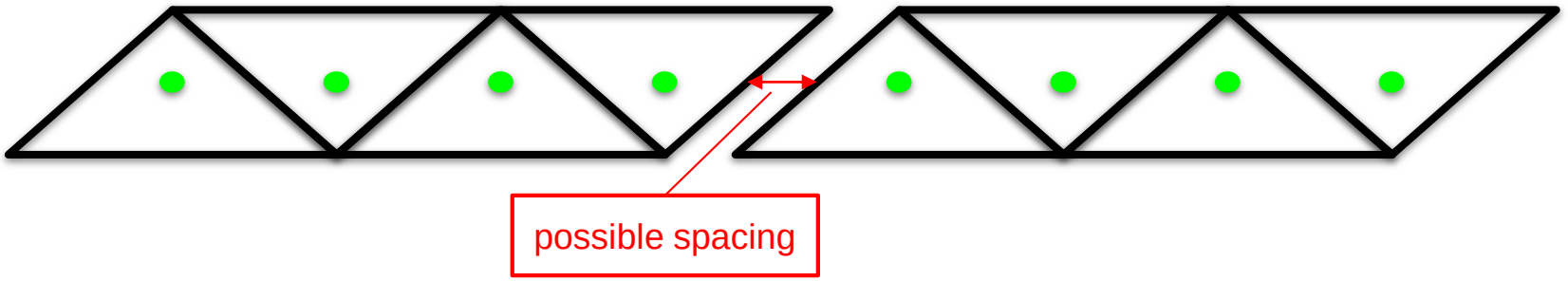


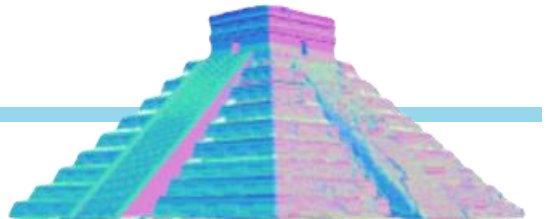
Total of 3 planes

X and Y view to determine 3D point in space. 28 x 48

Scintillator Shaft Dimensions

A single **"module"** will consist of 4 scintillator shafts, with possibly a small spacing between each module





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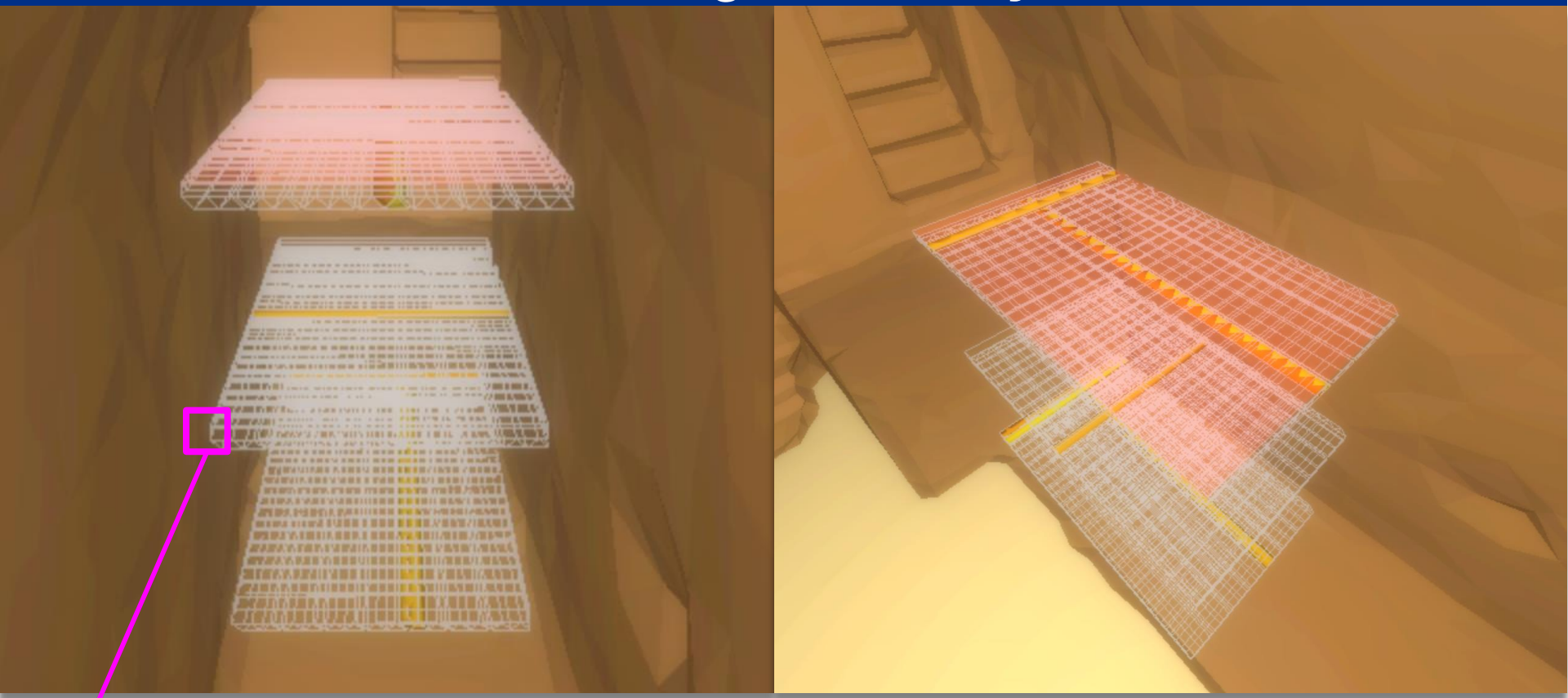
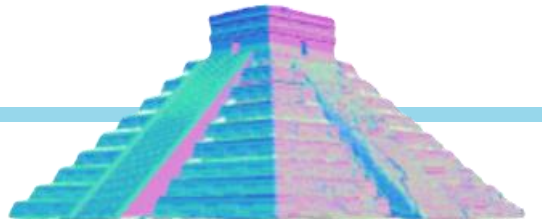
Sensor Fitting into the Pyramid



Extremely tight fit, probably only a few centimeters of space



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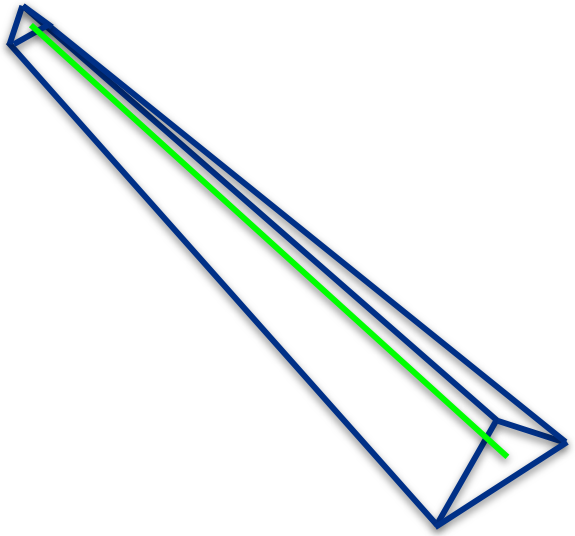
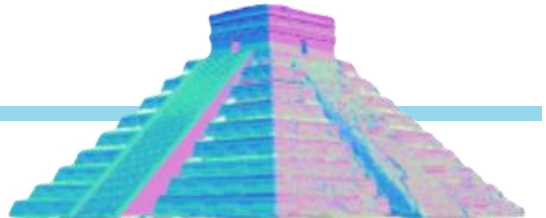
Scintillator Shaft

The green tubing in the middle is **wave-shifting fiber**. The light that hits it is mostly blue/uv, it is absorbed and must emit at a lower frequency and turns green.

When a muon crosses through the shaft, the wave-shifting fiber will light up ever so slightly, and the detector will measure this flash amount as data.





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Purpose and Build of a 3D Display

The Problem:

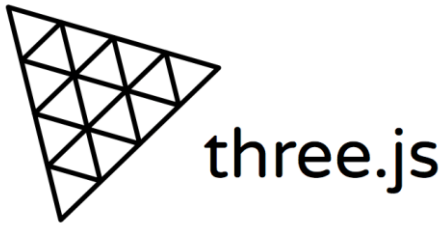
The pyramid team needed a live, real time 3D display that can help them monitor, analyze, and optimize their sensor positioning, angle, and design.

- The entire display has to be **to scale** in terms of meters
- The sensor should display the **paths of the muons** through the pyramid
- The acceptance cone of the sensor should show *what part of the pyramid is being scanned*
- The sensor model should have its *angles and positioning adjustable*

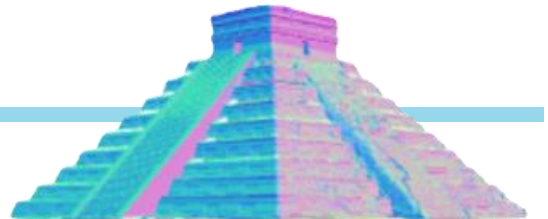
The Build:

- The entire display will be built using javascript
- *The calculated scale: 13 units in 3D render distance is equivalent to one real life meter*

The code will use **Three JS**, an efficient and industry standard 3D rendering library.



The code will also use Dat GUI, which is also an industry standard GUI rendering library.



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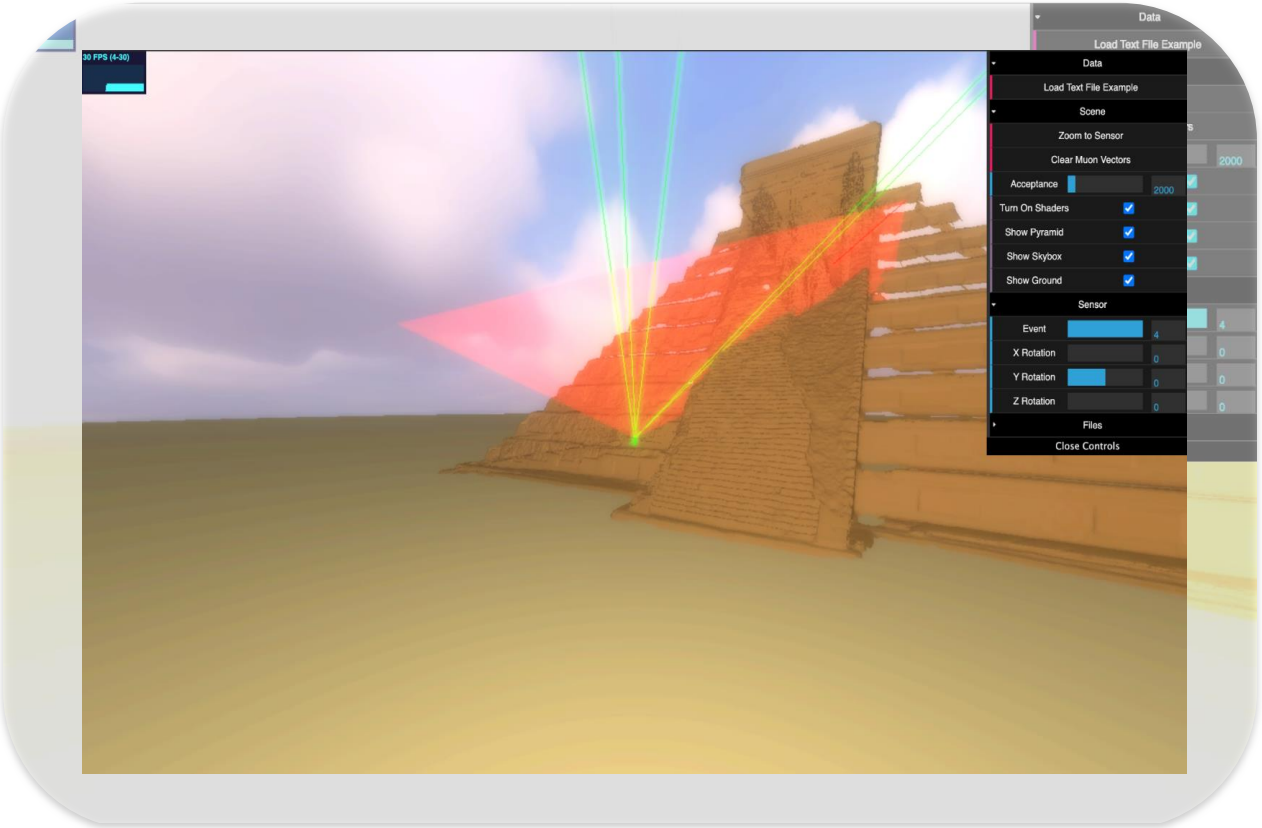
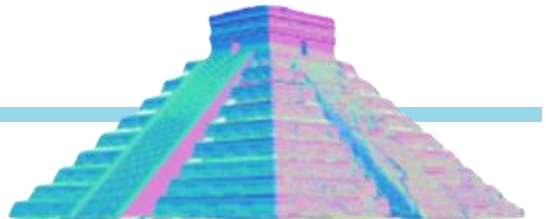
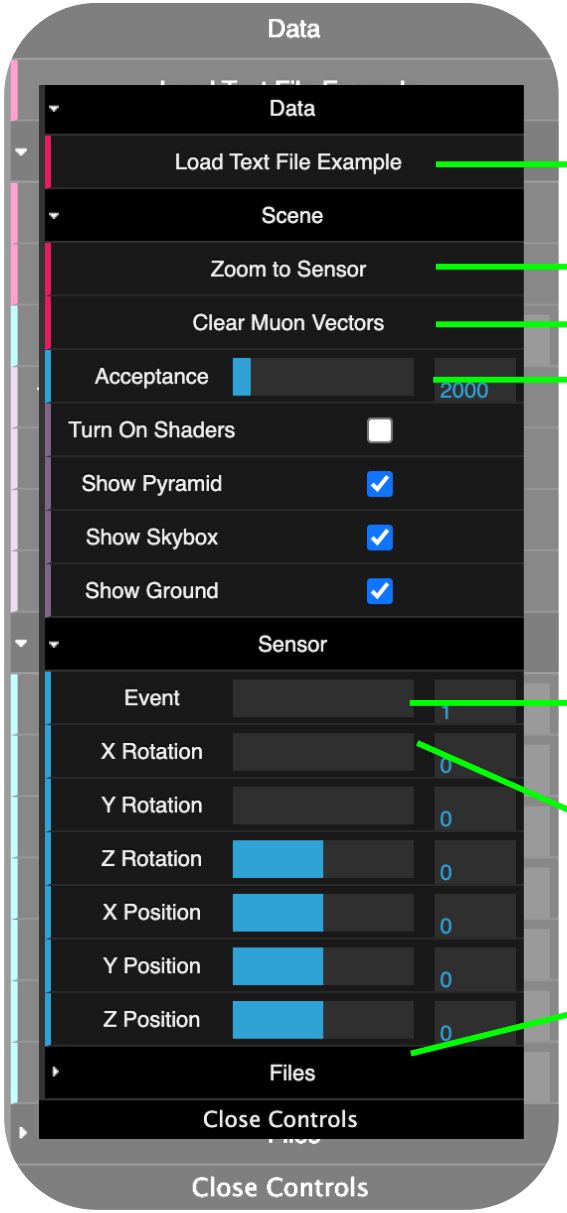
3D Display Overview



- Acceptance Cone (in red)
- Muon Vectors (in green)
- Pyramid Model
- Accurate and to Scale
- GUI Control
- Performance display



GUI Overview



For the pyramid team's future development: A file loading feature that will let the user manually upload data

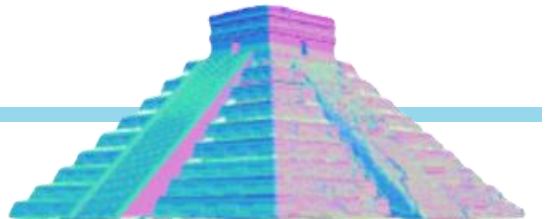
Lets the user zoom onto the sensor for convenience

The muon vectors can be cleared if needed

The acceptance cone's length

Allows the user to load each event, which will have muon vectors and highlighted shafts that show muon hits.

Important controls that allow the pyramid team to optimize and adjust the sensor to scan the most area.



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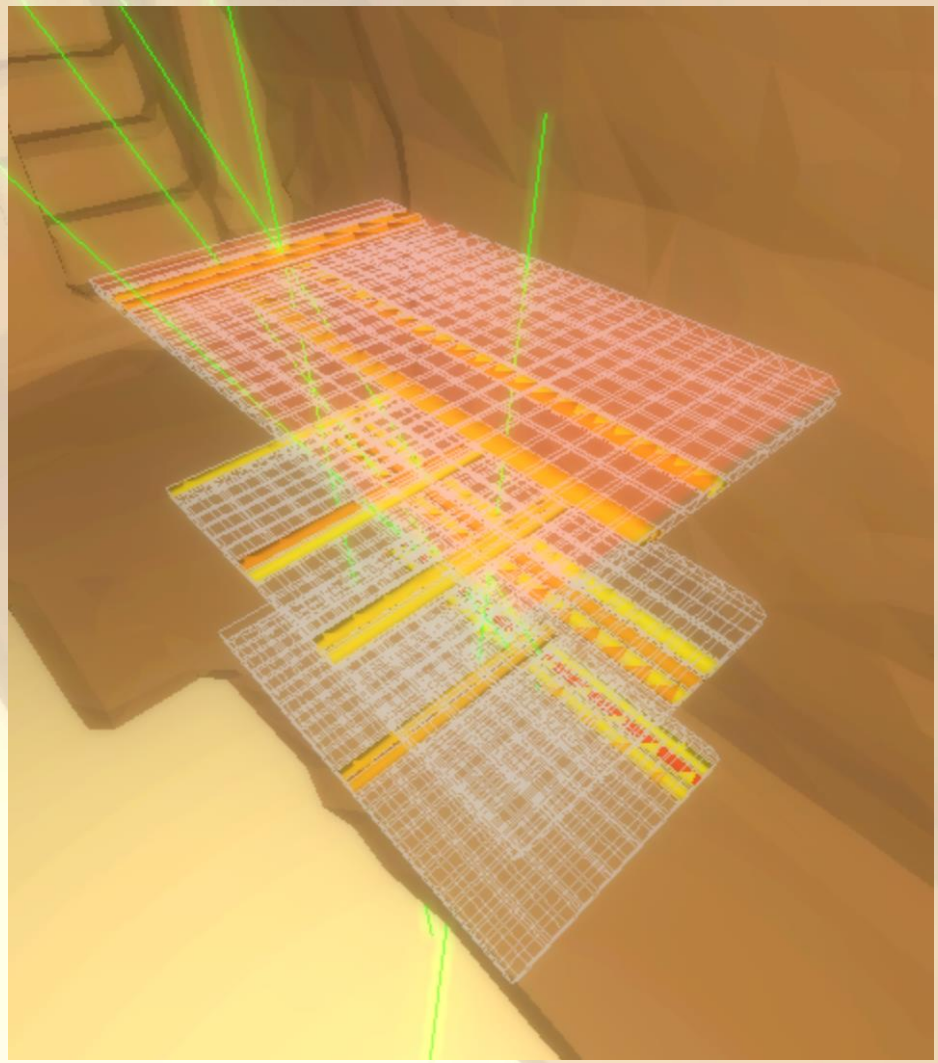
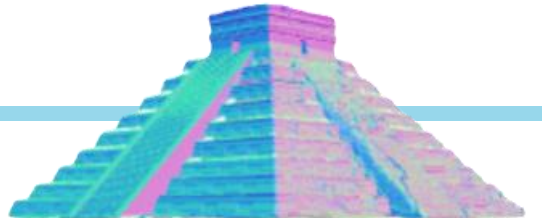
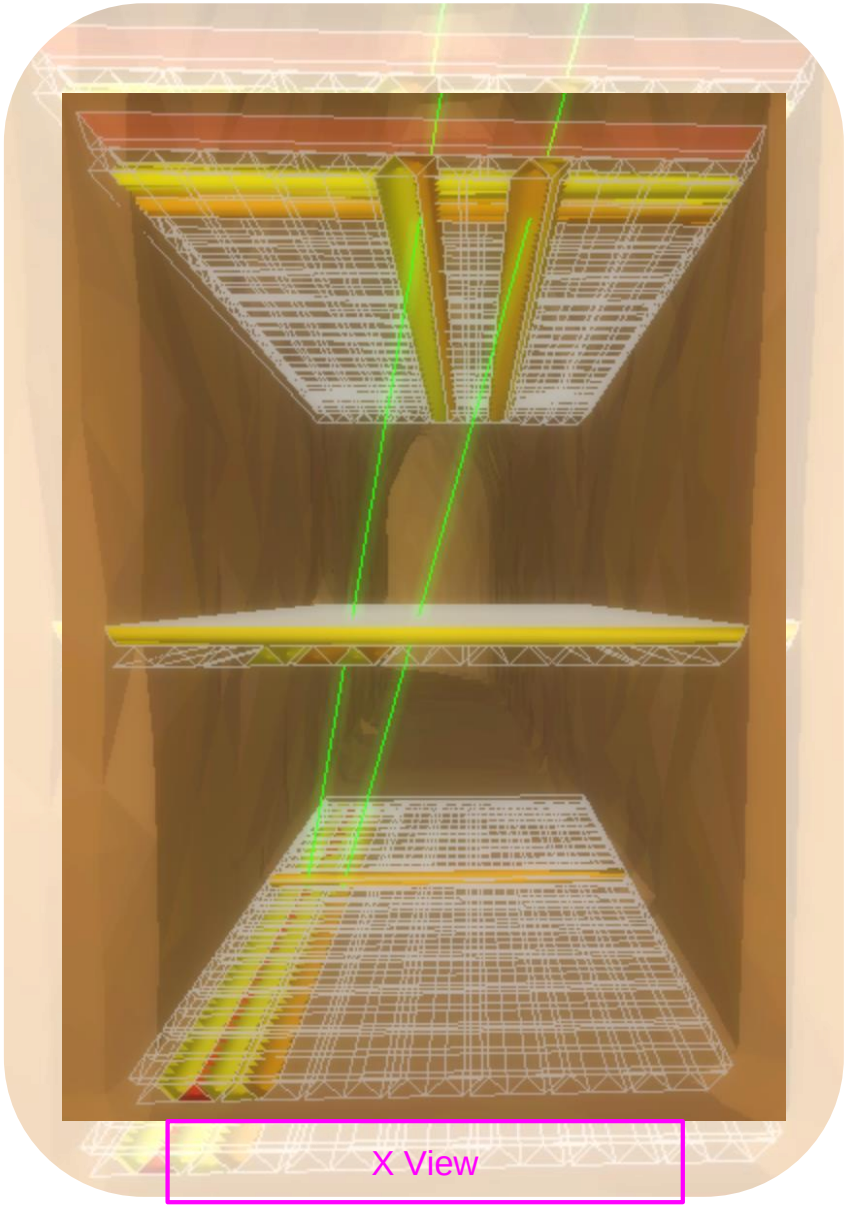
Muon Tracking in the Sensor

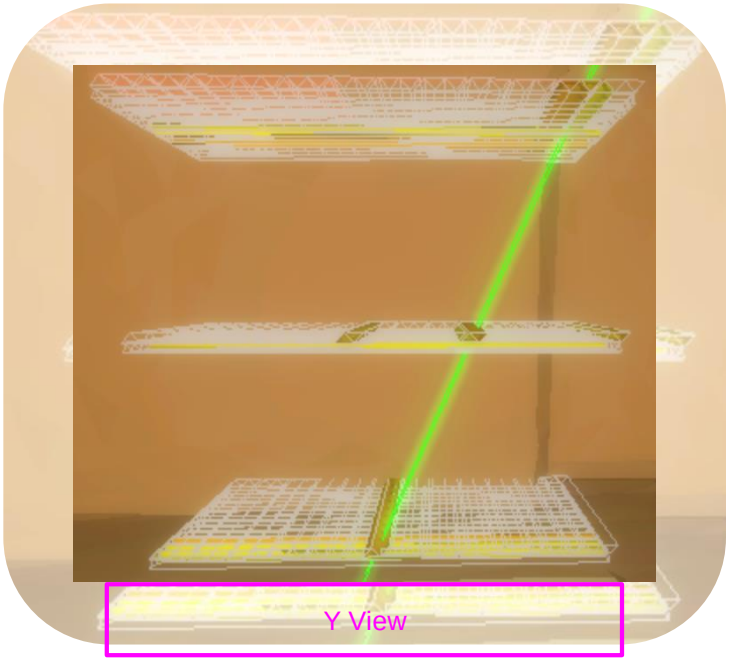


- Muons will hit the scintillator shafts and produce a value
- The X and Y arrays of shafts will help create a 3D point in space
- The 3D points in space will then be vectorized to create a traced path of the muon, called a **“muon vector”**
- An algorithm is needed to effectively determine exactly the muon path



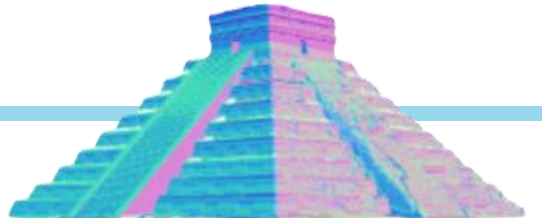
Pattern Recognition Algorithm for Muon Path (Part 1)





When a pair of scintillators are lit up, a muon most likely has hit it. There needs to be an **interpolation** between the pair to determine the exact point between the two.

Currently, we simply take the ratio between the two values of the pair. There needs to be a study done no this, possibly using Monte Carlo simulations.



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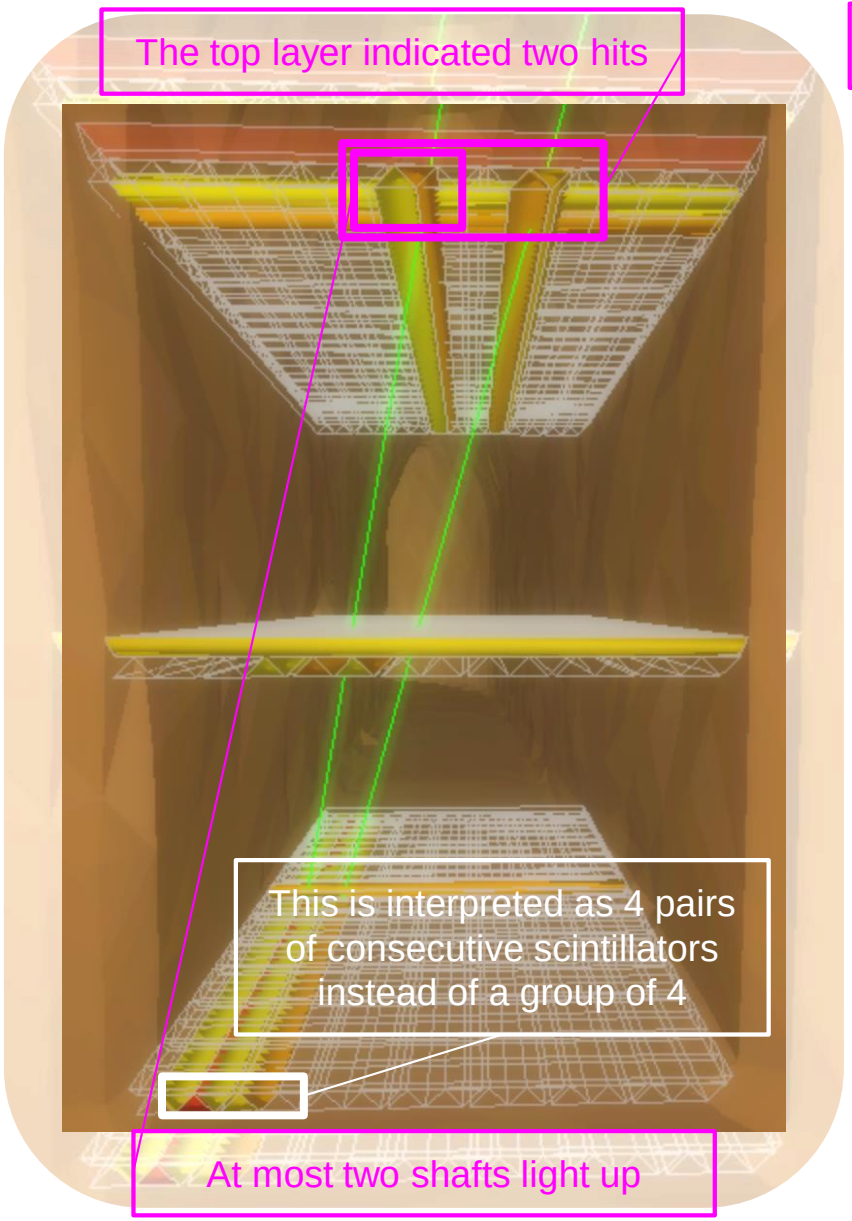
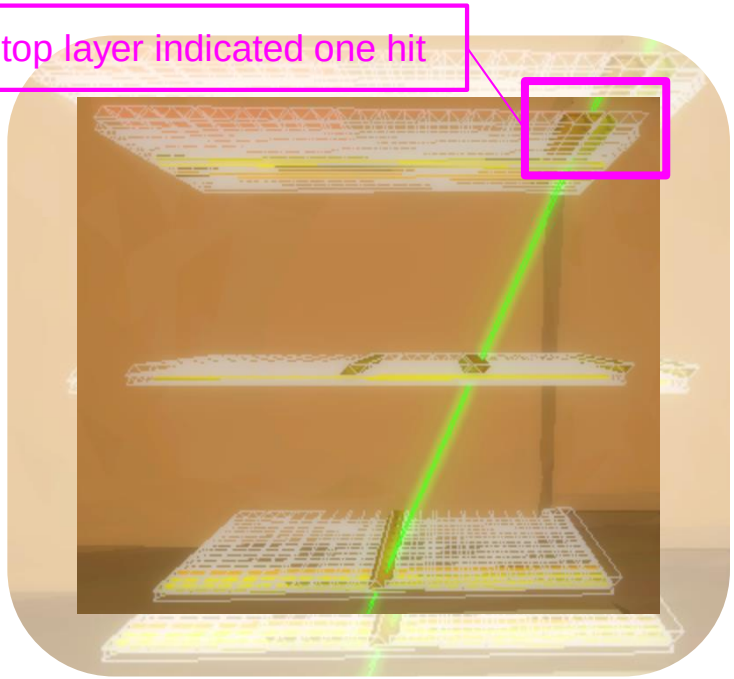
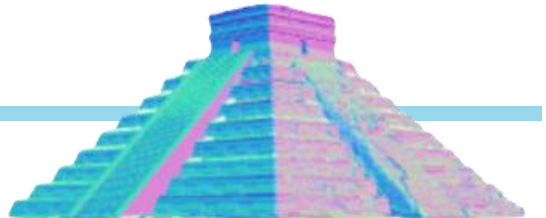
Pattern Recognition Algorithm for Muon Path (Part 2)





These are the assumptions and restraints for the algorithm:

- Muons **cannot light up three or more scintillators**, else it does not intersect all three planes
- The lit up scintillators in the **top layer determine the number of hits**, since those are the most likely to create a correct path traversing all three planes
- Only consecutive pairs of two are taken, groupings of three or more are not possible



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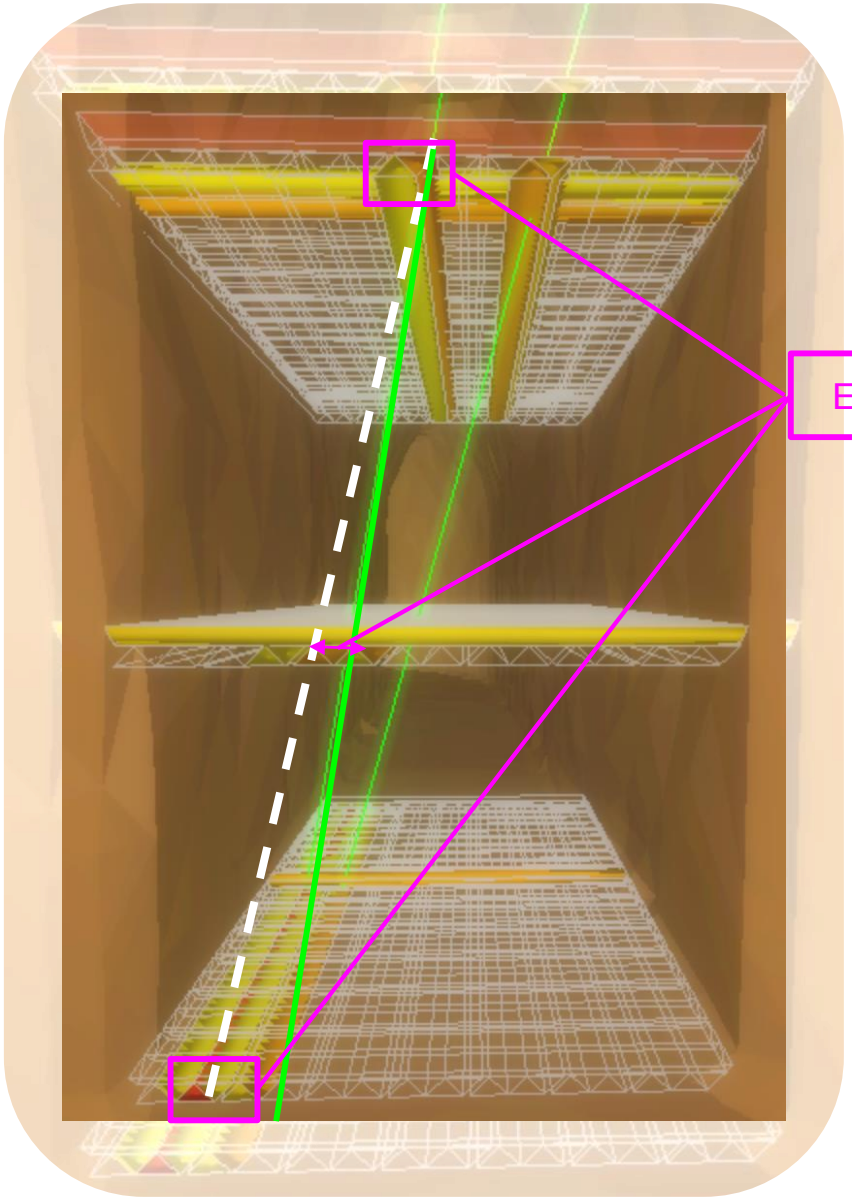
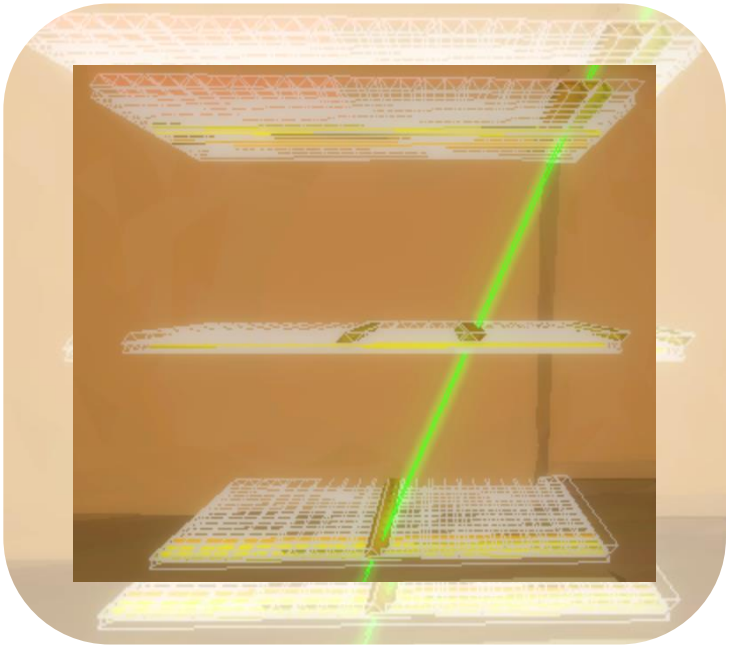
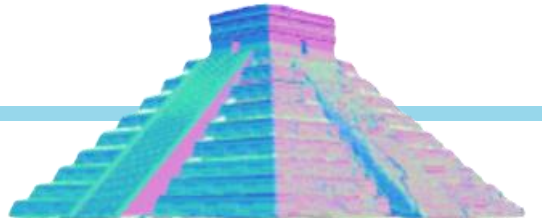
Pattern Recognition Algorithm for Muon Path (Part 3)





- An imaginary line is drawn between the interpolated points of the top and bottom layer.
- The point at which the imaginary line intersects the middle plane is used to calculate the closest distance to any scintillator that is lit up
- This distance along with the hit value of the top and bottom layers, are all factored into an “efficiency” value for that case.



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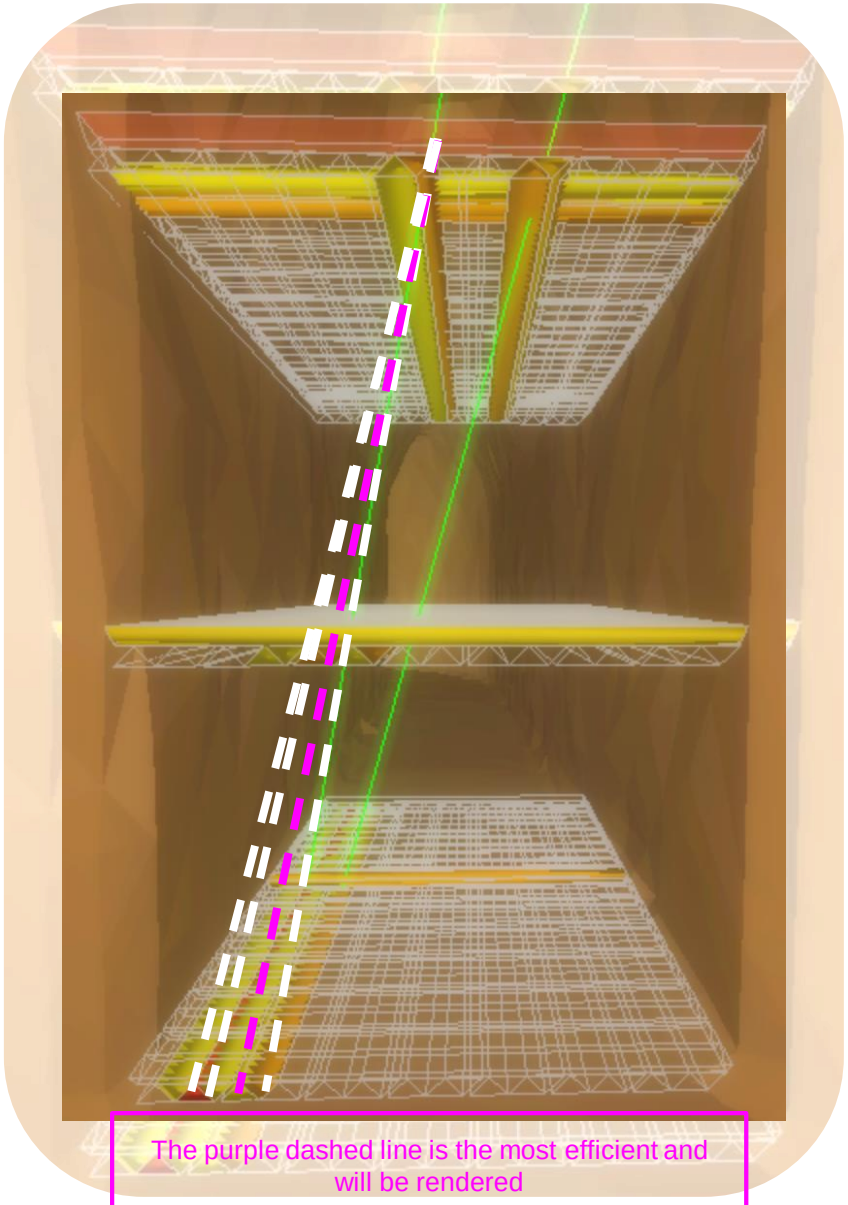
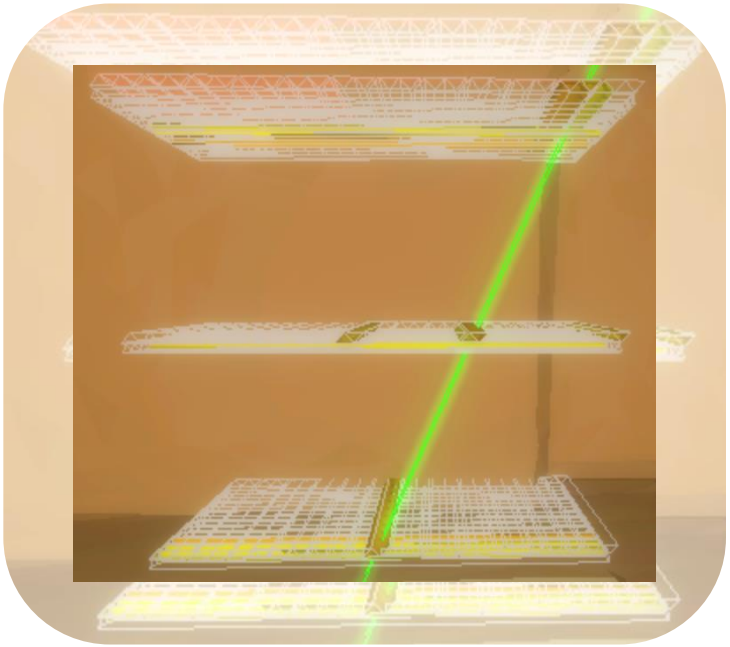
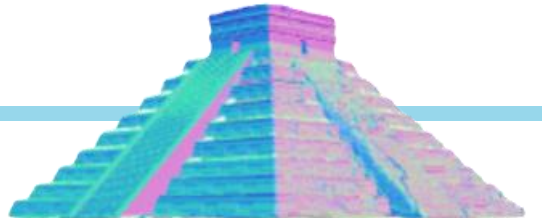
Pattern Recognition Algorithm for Muon Path (Part 4)



The purple dashed line is the most efficient and will be rendered



- The algorithm will find all possible imaginary lines and assign it its calculated **efficiency value**
- It will then sort and find the maximum efficiency value, and draw its corresponding imaginary line.
  - This will be the best estimation for the path of the muon and will be rendered into the scene



Pattern Recognition Algorithm for Muon Path (Part 5)

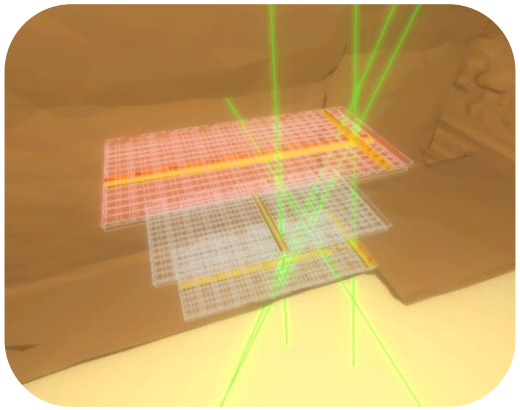
This current algorithm is very **basic and limited**

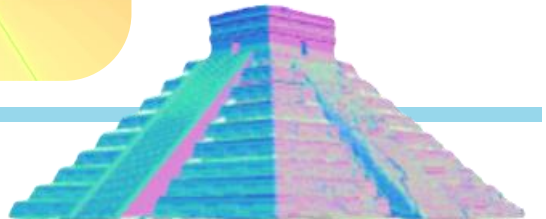
Recommendations for future development:

- A study needs to be done on the interpolation to be mathematically correct in determining the moun hit between two scintillators

- A study needs to be done on determining the efficiency value and other ways and factors to create the best estimation for the muon path

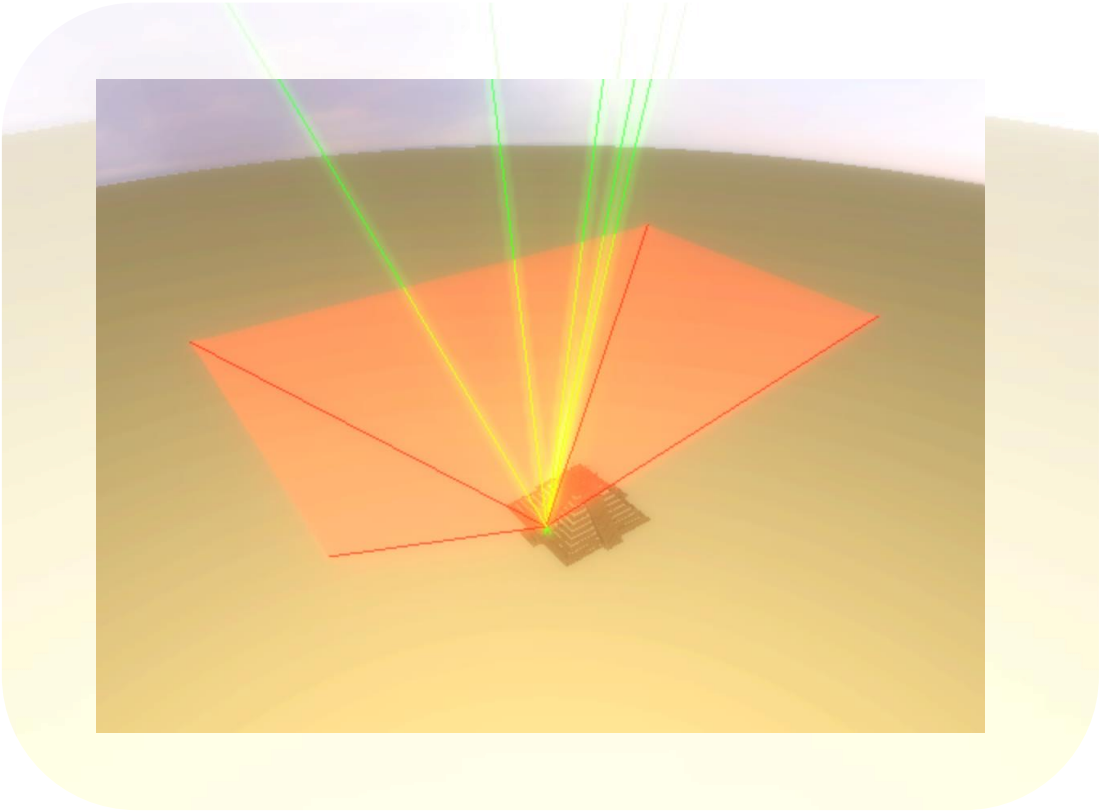
- The code currently only takes **distance in the middle plane** as a factor for its efficiency value, and is yet to be implemented completely.





Acceptance Cone and Sensor Adjustment

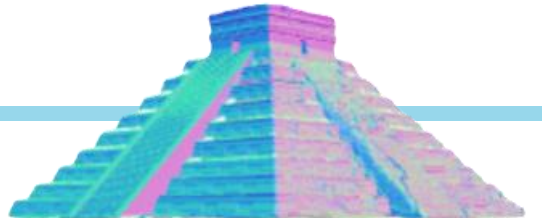
The **Acceptance Cone** (red below) is a visualization of the possible volume the sensor can scan



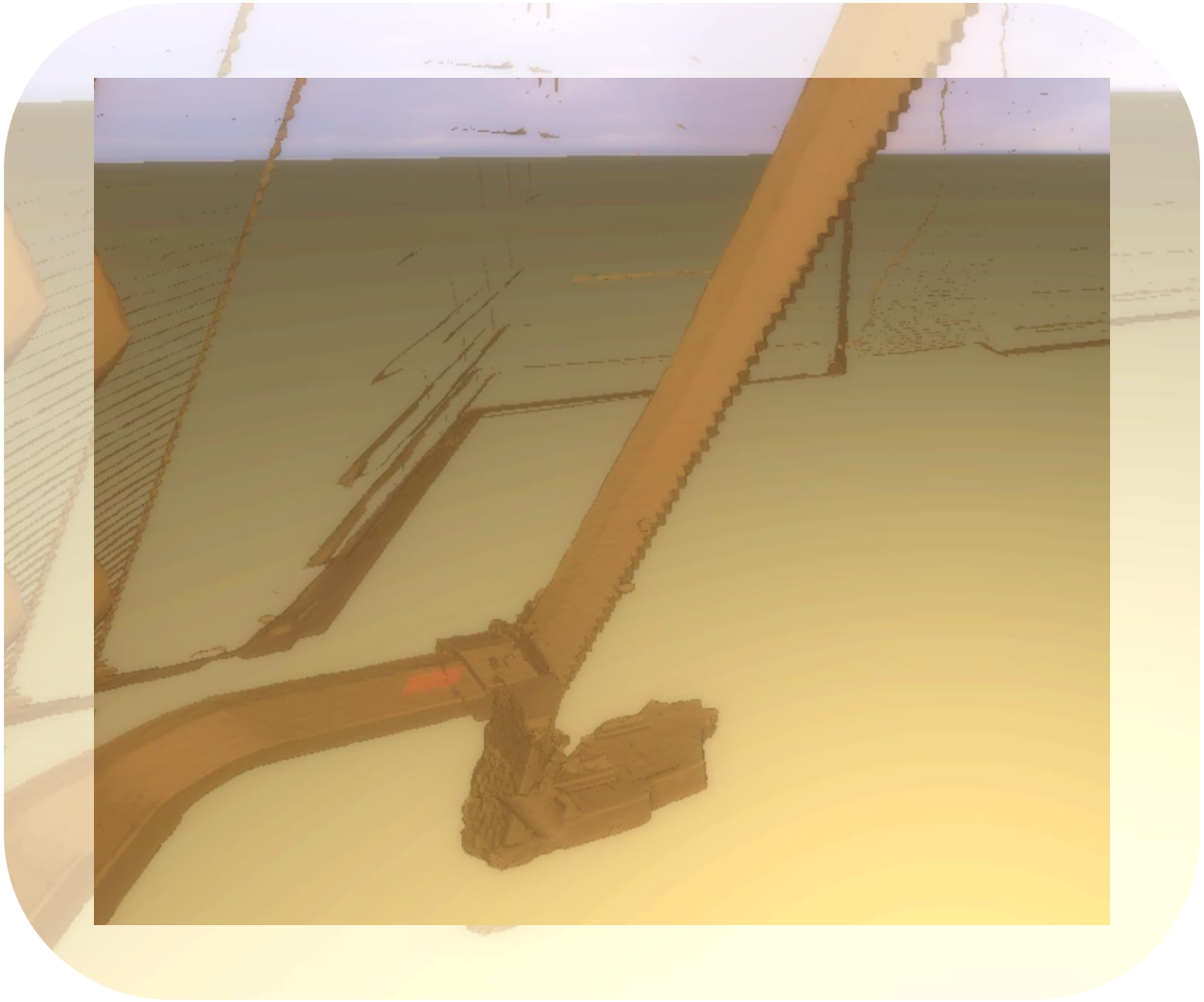
The adjustment of the angle of the sensor allows the pyramid scientists to find the most optimal positioning

The acceptance cone is determined by calculating the bounding box of the sensor and using its **space diagonals** to define the edges of an upside-down pyramid.

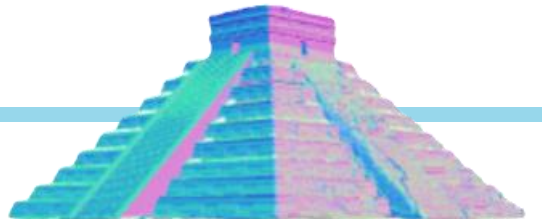
The red transparent pyramid represents the volume in which muons can potentially hit the sensor, *encompassing the most extreme paths for the muons*.



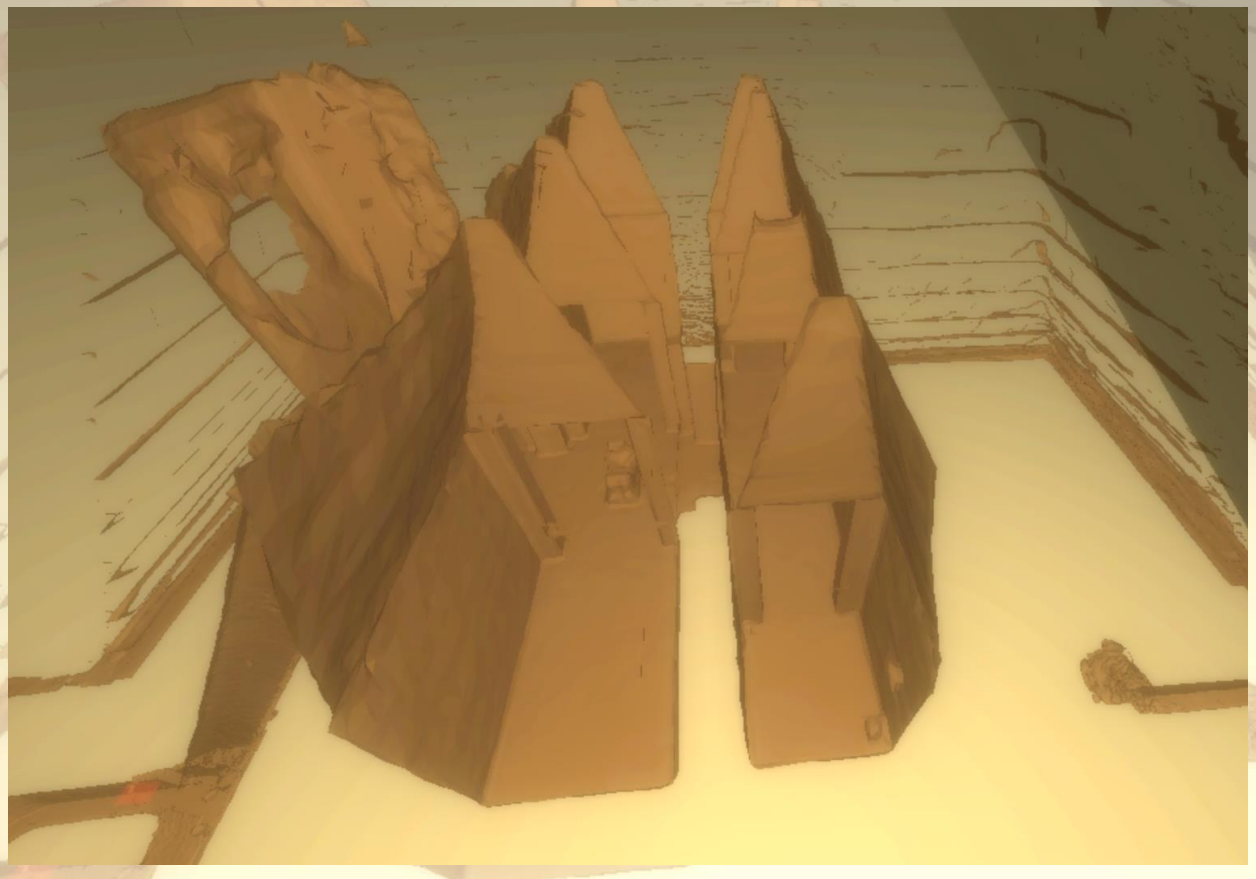
View of Pyramid Model (Part 1)



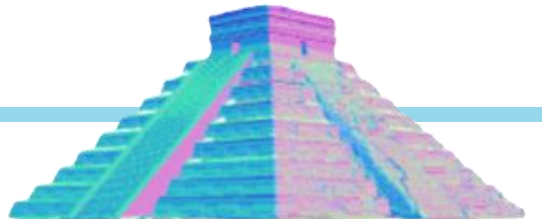
Stairwell of the north tunnel



View of Pyramid Model (Part 2)



Chambers at the top of the stairwell



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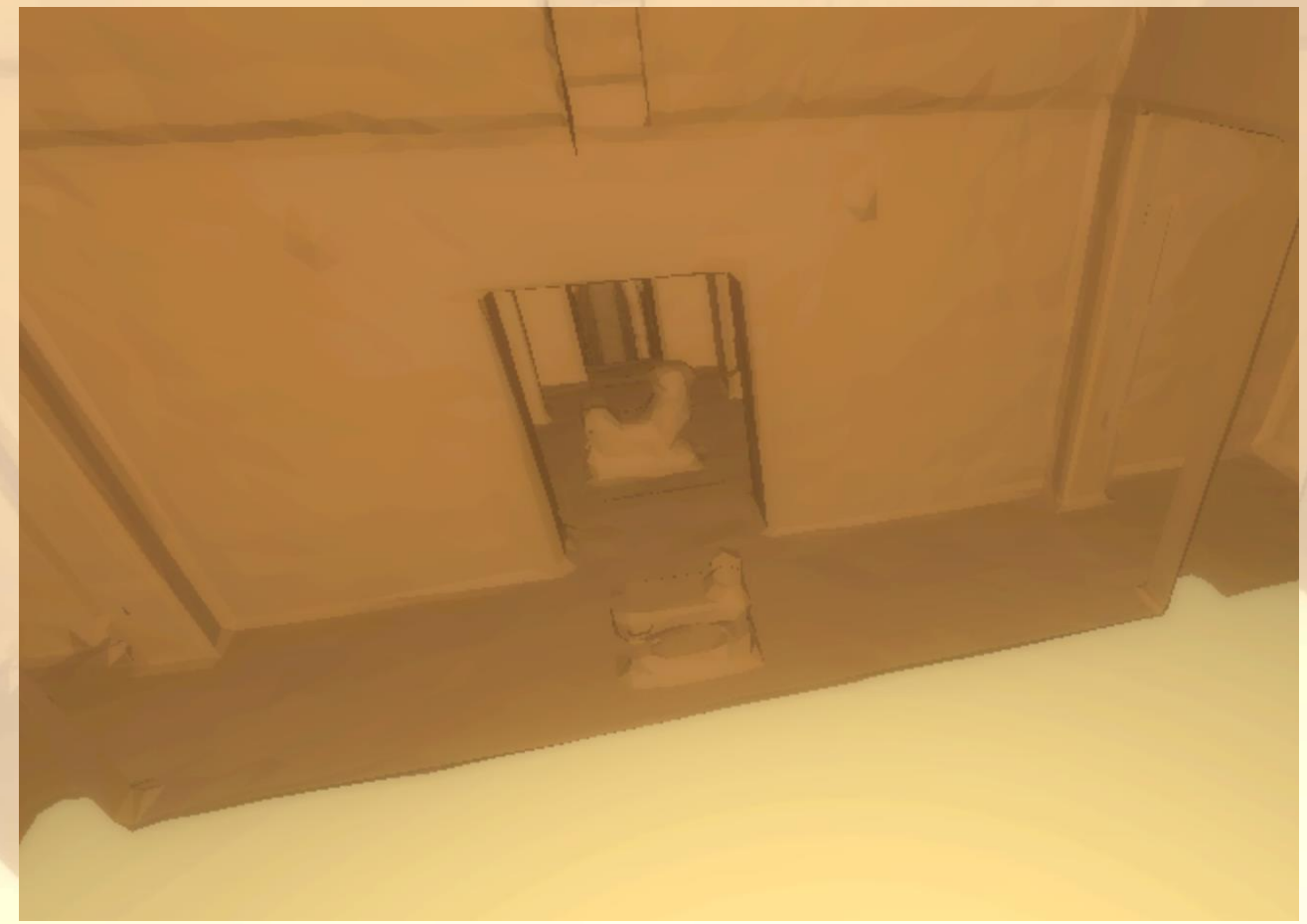
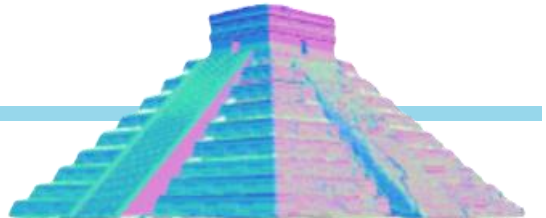
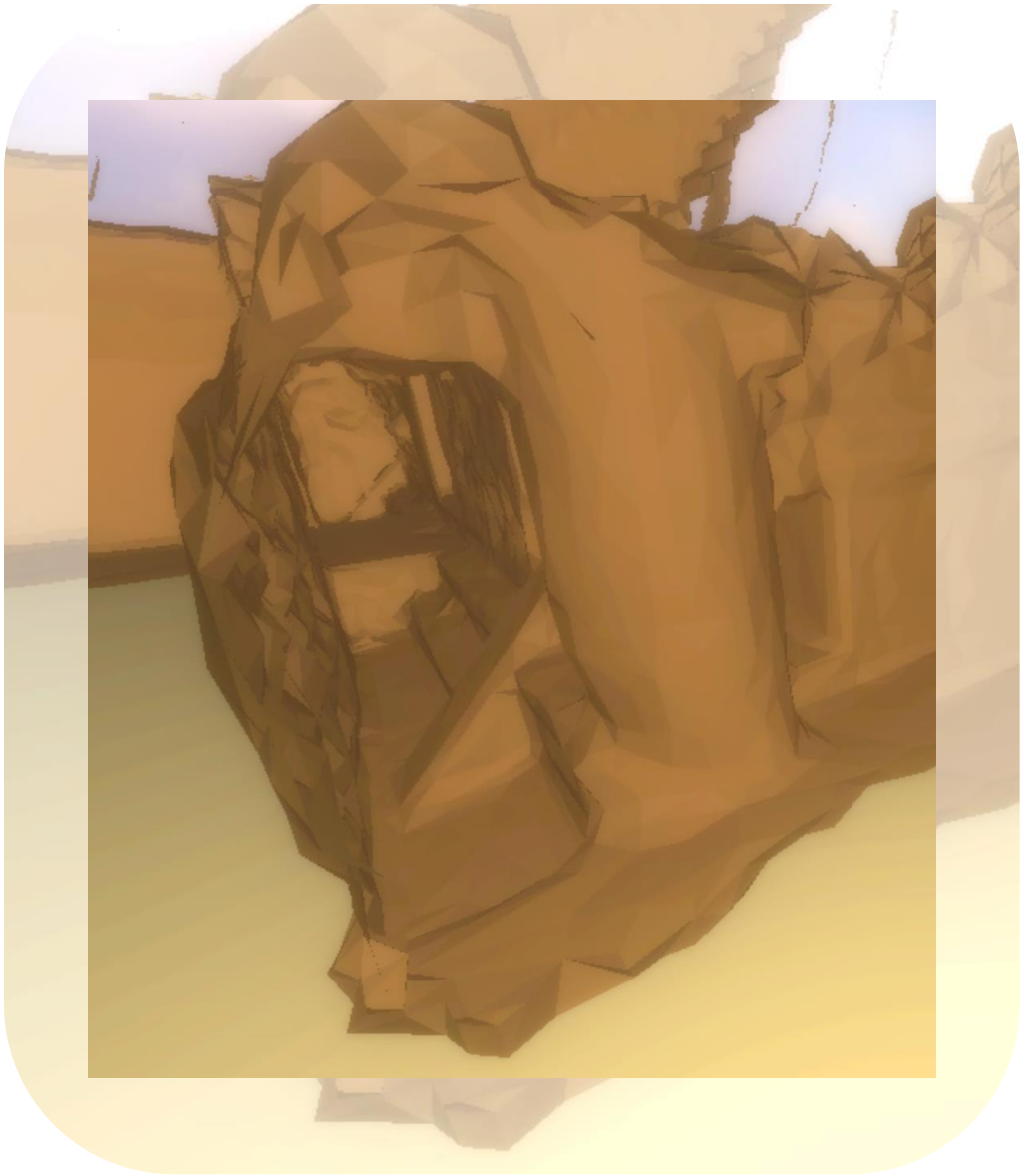
View of Pyramid Model (Part 3)



Jaguar statues inside top chamber



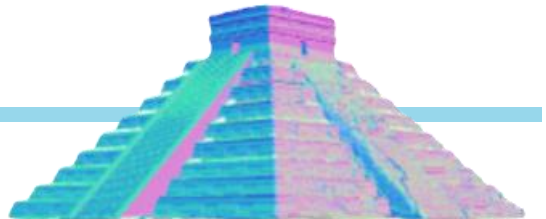
View of Pyramid Model (Part 4)



Pillar and possible secondary pyramid steps inside north tunnel

Based on current observations, the Mayans may have built pyramid on top of pyramid, resulting in the current structure we see today

Discovery of hidden chambers will lead to new found evidence of Mayan culture



LIVE DEMO

Link

The website will be eventually updated on i2u2 e-labs at
https://i2u2.org/elab/cosmic/pyramid

Currently, the code and website is hosted on glitch.