Participants:

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Purpose:

The calorimeters at The Compact Muon Solenoid (CMS) at the Large Hadron Calorimeter (LHC) at CERN have had a large exposure to radiation with considerable damage to them. They need to be replaced by more robust radiation hard materials that still maintain a high sensitivity to particle detection. We are testing materials that could replace the current materials that would be more robust to radiation damage while maintaining sensitivity to particle presence.

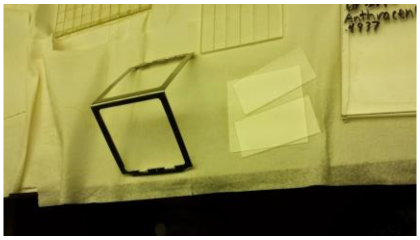
To this end, we are depositing organic scintillating materials on Quartz plates in an attempt to create detection materials that are radiation hard yet maintain sensitivity to the passage of particles.

Method:

Quartz plates have been shown to be one of the few radiation hard transparent materials, especially to Ultraviolet radiation (UV). When high-energy particles pass through Quartz, they can create Cherenkov radiation in the violet color range. This radiation is very weak compared to some organic substances that fluoresce light. To combine the sensitivity of the organic substances along with the transparency and radiation hardness of quartz, we will attempt to coat the quartz plates with the organic materials to attain the best of both.

The Quartz plates were coated by vacuum deposition with the organic scintillation chemicals. Vacuum deposition was chosen because it would adhere the substances to the surface of the Quartz plates somewhat evenly. The plates were then annealed in the absence of oxygen to make the depositions more transparent. Once the organic scintillation material was fixed between two plates, wave-shifting fibers were optically coupled to the quartz plates to pick up the light created by the scintillation. The light from these fibers would then be measured by a photo detector and translated into electronic data to be analyzed. This process would enhance the Cherenkov radiation from the plates and maintain the radiation hardness of the materials.

Four materials were slated to be tested this way: Naphthalene, Stilbene, Anthracine and P-terphenyl (PTP). All of these substances are known to scintillate with UV radiation. PTP has been used for this before so it was a standard to compare against the others. Each was tested for workability, sensitivity and compatibility with the Quartz plates.



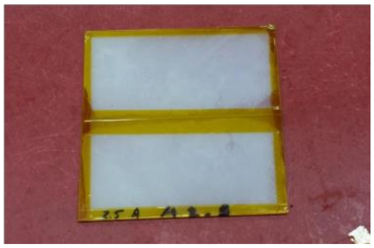
Procedure:

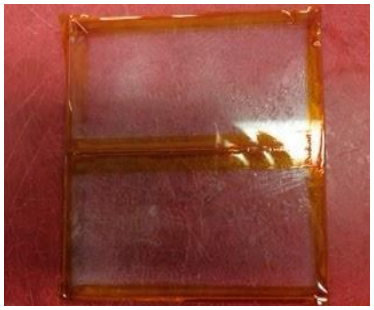
The materials used in the vacuum chamber consisted of 10 cm x 10 cm x 0.1 cm and 5 cm x 10 cm x 0.1 along with an Aluminum “roof” to hold them above a glass cylinder with a Tantalum “boat”. The boat was suspended in the cylinder below the plates by two electrodes. A high current could pass through the boat in order to heat it up.

Prior to evaporating the chemicals, the vacuum must be pumped down to at least 10^{-6} torr. In order to achieve this very low pressure, everything was cleaned (with acetone while wearing gloves) of all fingerprints and dust to prevent outgassing. All components in the setup were also made of materials that did not outgas. After everything was cleaned, the vacuum pump was pumped down to at least 10^{-6} torr before heating up the boat to begin plating.

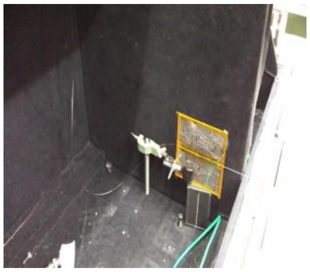
The materials were heated up by a current passing through the Tantalum boat. The contents were heated up slowly, using a rheostat to adjust the current, to the melting temperature. Using the Aluminum stand to hold up the panes, the panes were then coated by the evaporating chemical. The Aluminum roof and the glass cylinder were used to prevent the bell jar from being deposited with the chemical.

After plating was complete, the plates had a cloudy look. The material needed to be crystallized in order to readily pass light through them. The plates were removed and taped together with Kapton® high-temp tape, making sure to have the scintillation chemicals in between them and a gap between the half-plates that is large enough to allow a fiber in between.

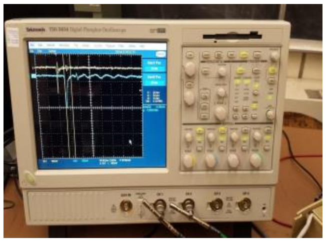




The plates were then placed in a chamber of an air-tight oven. The chamber was evacuated, then filled with nitrogen to prevent oxidation. The chamber was slowly heated up to the chemical's melting point and slowly cooled to anneal the chemical to a crystalline form. The plate was removed after the annealing process was done, the groove was greased with optical grease, a blue optical fiber was inserted into the greased groove, and the groove was re-greased with the optical fiber inside. The tape was placed over the top of the greased groove.



A test was done on the plates to see if they would create light. The plates were put in a dark box and exposed to a 337 nm UV pulsed LASER. The fibers were fed into another dark box where their light was fed into a Photomultiplier Tube (PMT). The pulses of the LASER were monitored with a photodiode and compared to the pulses produced by the activated PMT on an oscilloscope.



Results:

Naphthalene and trans-Stilbene were not successfully plated. The Naphthalene and trans-Stilbene were too volatile. Both chemicals evaporated before a strong enough vacuum was created to begin the deposition process. If they are to be considered, a different process is necessary.

A control plate with no coating in between the panes was made to compare the scintillation. The control had a very low reading when hit with the UV laser.

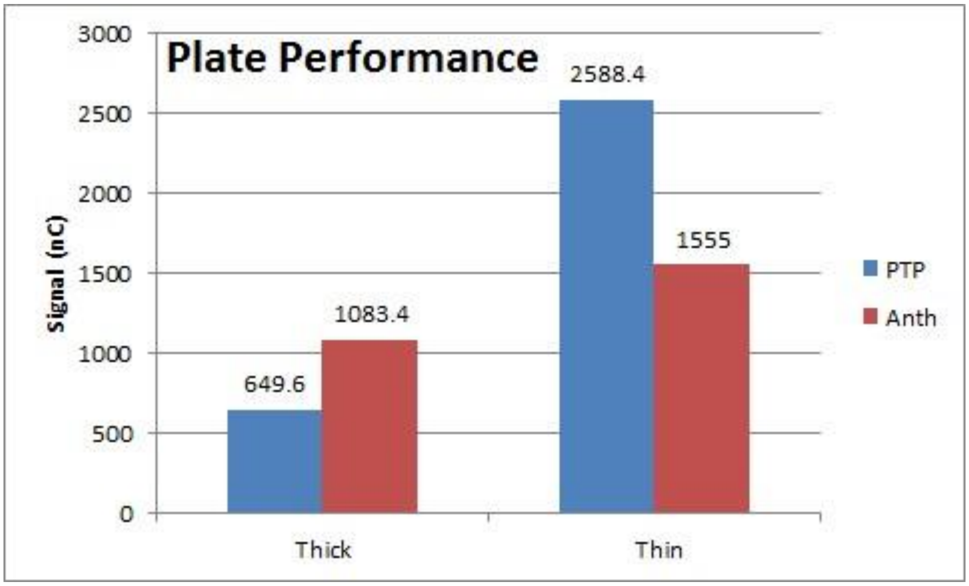
The 1,4 diphenylbenzene (para-Terphenyl or PTP) plated and crystallized in the oven and scintillated. The desired thickness for PTP was 50 micrometers. The actual thickness we got from 2.5g of PTP was 45 micrometers. The plate with 5.0g of PTP had a thickness of 554 micrometers. When the optical fiber was fed into a PMT and placed in a dark box and was hit with the UV LASER, the oscilloscope did detect a successful signal with the blue fiber.

The Anthracene also plated successfully and cleared up in the oven, and scintillated. The desired thickness for Anthracene was 50 micrometers as well. The actual thickness for 2.5g of Anthracene was 31 micrometers. With 5.0g of Anthracene, we achieved a thickness of 41 micrometers. When tested in the darkbox we found that the blue fiber did not sufficiently wave shift and there was no signal at the end of the fiber. The Anthracene emits a higher wavelength than PTP so a higher wavelength wave-shifting fiber was needed. In an attempt to change results, a green fiber replaced the blue fiber which created a successful detection.

After changing the fibers to the green wave-shifting fiber, signals from both substances were taken. The thin films seemed to do better than the thick ones. The thin PTP was the best and the thick PTP was the worst with the Anthracene performing in the middle. The results of the measurements are expressed in the following table and graph: **Table of Data:**

	Plate Testing	
Plate	**Pulse (nC)**	**Film thickness (um)**
PTP 5.0	649.60	554.14
PTP 2.5	2,588.40	45.72
A 5.0	1,083.40	41.91
A 2.5	1,555.00	30.90
control	10.26	

Graph of Plate Performance:



Further Work:

Finding a way to plate Naphthalene and trans-Stilbene will be helpful. The more options there are, the better. Then, mixing and testing different combinations of the chemicals to get the desired properties and emitted wavelengths could help perfect results. Finding a way to accurately plate Cerium tribromide without wasting it due to its expensive nature would also be interesting. Testing varying thicknesses of the quartz plates and the plated material will be helpful to see if the integration of the optical fiber into the plate can be improved. Stacking plates should also be investigated to see how they perform.

Quarknet 2014 Report - University of Iowa

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Purpose:

The purpose of this project is to create an easily replicable, interactive, 3D scale model of the Compact Muon Solenoid (CMS) at CERN. The model implements two current technologies: an Afinia 3D printer[1] and Arduino Uno[2] for its construction and functions. Once completed, the 3D design can easily be shared and printed throughout the world by anyone with a 3D printer, while other components of the model can be bought and assembled based on the finished model. The actual functions of CMS are simulated by lights controlled by the Arduino electronics boards . An interface with a Silicon Photomultiplier (SiPM)[3] allows the model to use cosmic muons to mimic a particle collision, with LEDs lighting up the model correspondingly, all of which can be controlled via an application available to an iPad or iPhone. The model is meant to be used for educational purposes, providing a cheaper way to closely examine the construction and functioning of the Compact Muon Solenoid.

Method:

The design of the 3D model of the CMS[4] was accomplished by viewing schematics of the CMS and replicating it at a 1:60 scale[5]. Rather than producing one large piece of plastic in the general shape of the CMS, each major component of the CMS was printed and fitted together. The solenoid, being the largest singular piece of the CMS, limited the size of the 3D model, and thus the scale was based off the maximum allotted size of the model solenoid (12.7cm x 12.7cm). Additional parts, included to represent the functionality of the CMS, include the pixel detector, the preshower detector, the Forward Hadron Calorimeter, the silicon tracker, the Electromagnetic Calorimeter (ECAL), the Hadron Calorimeter (HCAL), and the Muon Detector, complete with its iron plates. The model's parts are designed to be self-contained. A very minimal amount of glue is required for the pieces to hold together, as most parts interlock and wedge together, with an additional cradle holding up the structure itself.

The custom programmed Arduino Uno was used to control LEDs for display purposes[6]. The LEDs are capable of being turned on/off for each of the aforementioned parts of the model. A Silicon Photomultiplier Module (SiPM) is used to detect an actual cosmic ray muon which triggers the model to light up its components. This is meant to give a visualization of the muon stations in the CMS which help to track the muons given off from the high energy particle collisions. Compatibility with the iPad/iPhone was worked on using the iOS Developer software.

Results and Further Work:

A 3D printed, scale model of the CMS[7] at CERN was successfully designed and printed[8]. However, while the code and capability of the LED display implementing a Silicon Photomultiplier and controlled by an iPad app exists, each part of the project has yet to be combined. The scale model has been successfully designed, the code for LED compatibility has been written, and code for an iPad/iPhone application has been written, but these components, due to time constraints, have not been combined for the final idealized product. For future work on this project, adhesive LEDs--such as those offered by superbrightleds.com[9]--must be purchased and connected to an Arduino, and an interface, preferably wireless using the Arduino Wifi Shield[10]--must be made between an iPad/iPhone and the Arduino in order to control the model.

Beyond the further work for this project alone, it may be beneficial, due to the increasingly useful nature of 3D printing, to pursue the creation of a working 3D model of CERN itself, as well as many other scientific experiments that, due to their uniqueness and size, could benefit from a smaller model useful for the education and training of its use and purposes. And the general populace may find more interest and understanding in science if an otherwise inaccessible and abstract experiment became a tangible object which they could access and control simply via an iPad/iPhone.

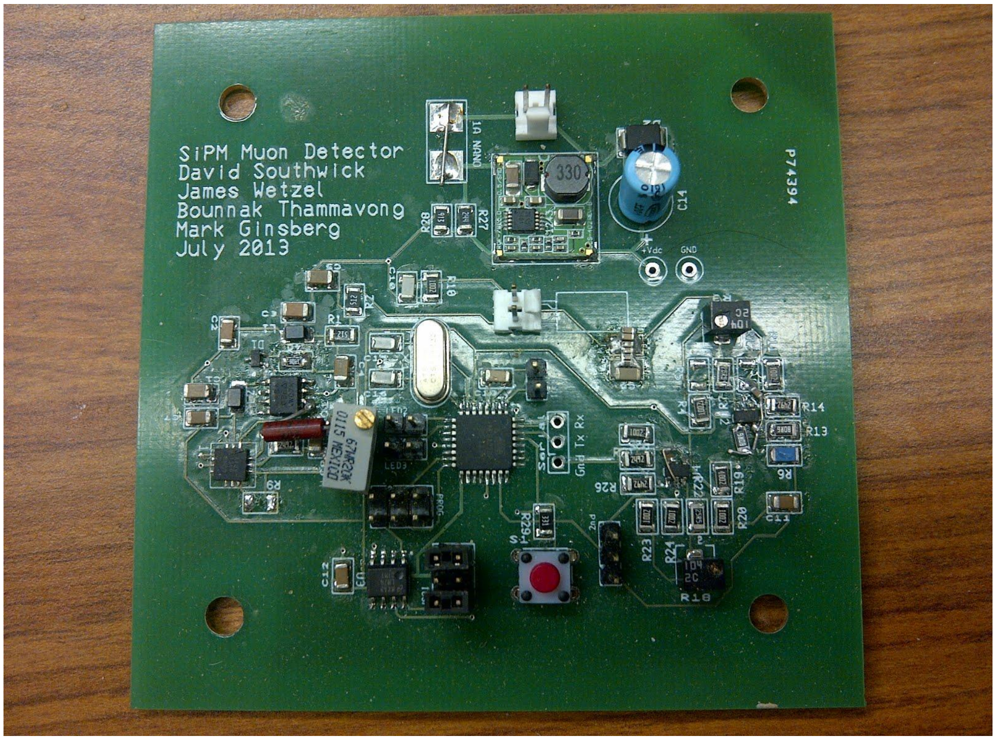
Photos:

1.)

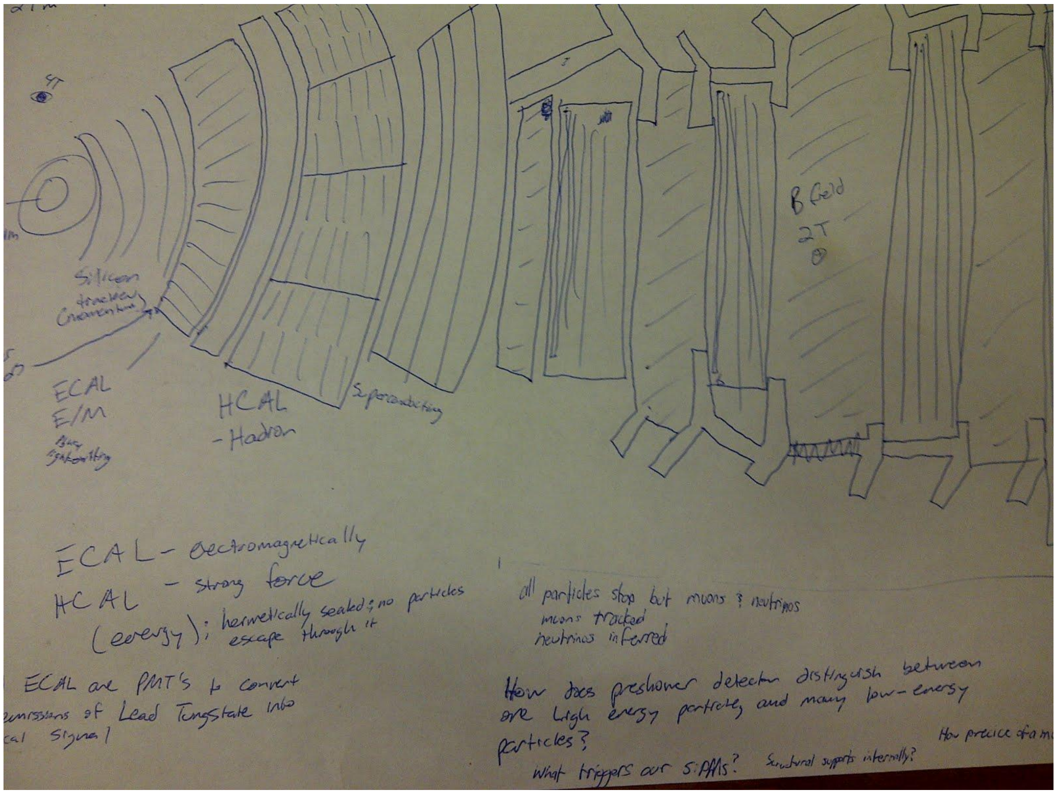
2.)


MADE IN ITALY
DIGITAL (PWM~)
UNO
ARDUINO
ON
RESET
ICSP
WWW.ARDUINO.CC
POWER
ANALOG IN

3.)


SiPM Muon Detector
David Southwick
James Wetzel
Bounnak Thammavong
Mark Ginsberg
July 2013

4.)



ECAL - electromagnetically
HCAL - strong force
(energy); hermetically sealed; no particles escape through it

all particles stop but muons & neutrinos
muons tracked
neutrinos inferred

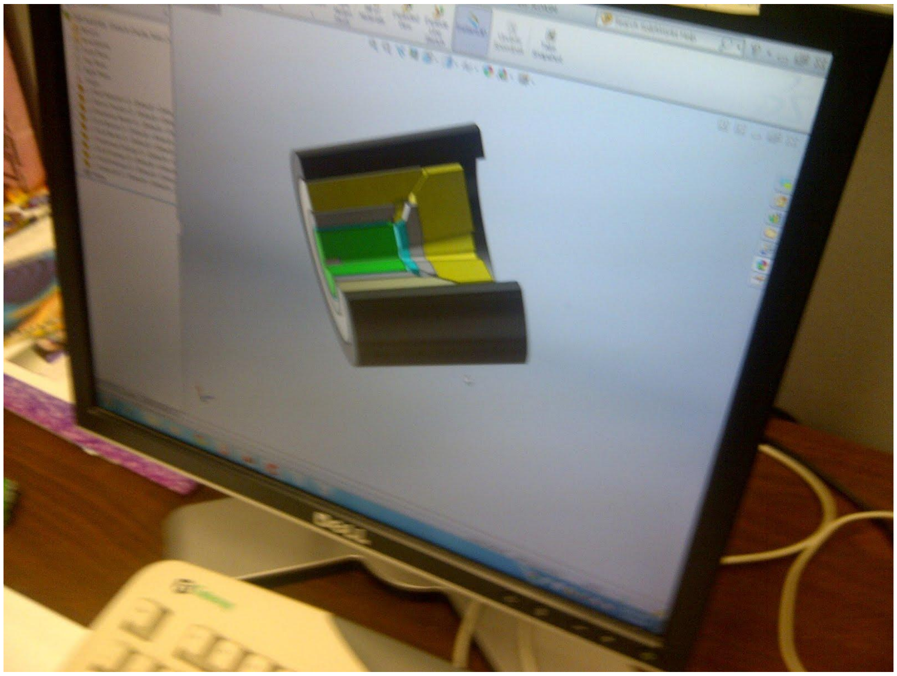
ECAL are PMT's to convert
emissions of Lead Tungstate into
cal Signal

How does preshower detector distinguish between one high energy particle, and many low-energy particles?

How precice of a m

What triggers our SiPMs? Structural supports internally?

5.)



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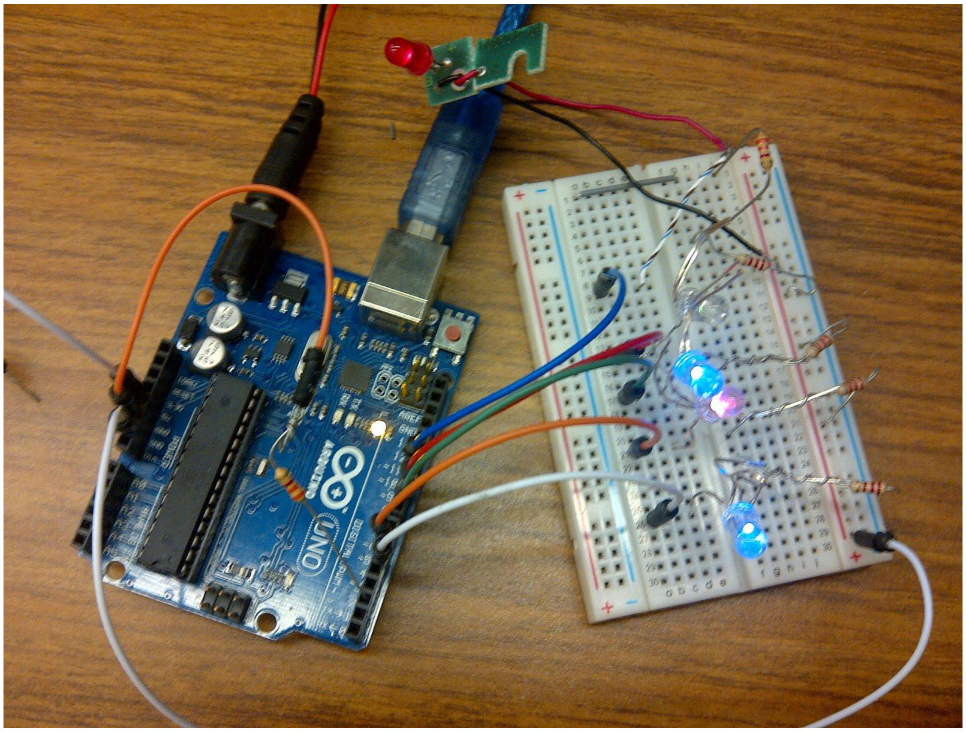

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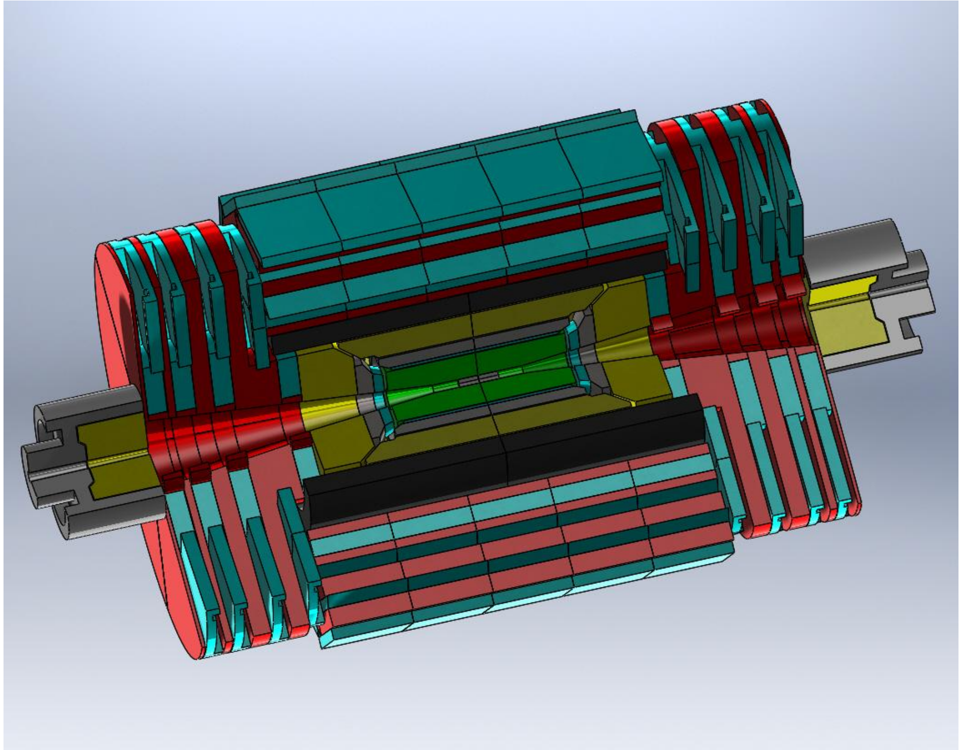

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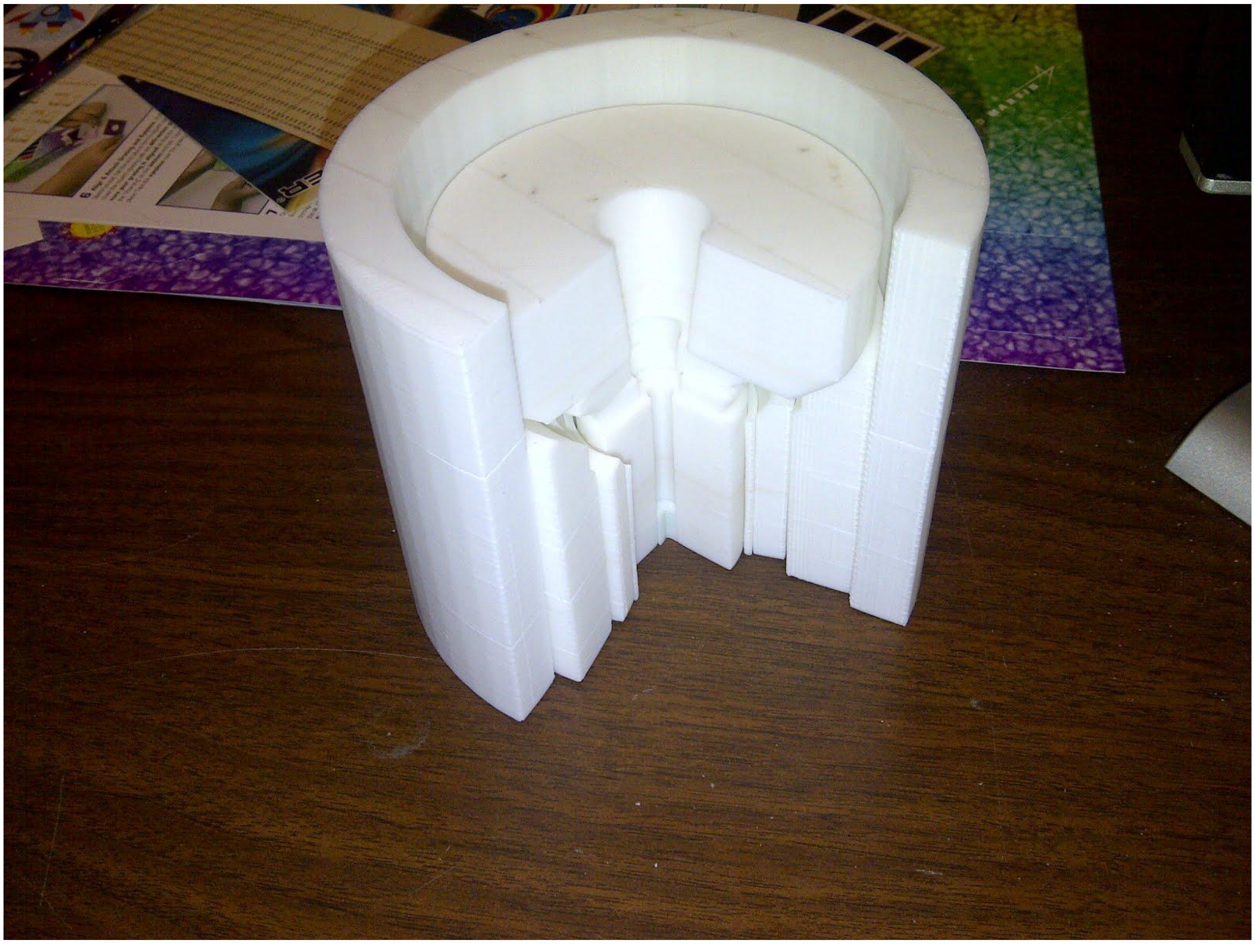

9.)

http://www.superbrightleds.com/moreinfo/rgb-bars-and-strips/high-power-rgb-led-flexible-light-strip--nfls-rgb/1468/

10.)

http://arduino.cc/en/Main/ArduinoWiFiShield