# Modification & Application of a 3D Printer for a Nuclear Physics Lab

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## Abstract

The process through which ideas are transformed into tangible objects has been revolutionized by the creation of the 3D Printer. In the Dynamic Nuclear Polarization (DNP) Lab, matter's nuclei are polarized through exposure to high irradiation and cryogenic temperatures. The incentive of using a 3D printer in a Nuclear Physics Lab allows for the creation of tools which can withstand such extreme environments. The printer used began as a stock *Prusa i3*[1], but after extensive modification, gained the ability to print a variety of filaments suited for lab use. In the future the printer will be used to create a polarizable target stick cup chamber out of a fluoroplastic named KEL-F, which has never been 3D printed before.

## Assembly of Stock Printer

-Began as *Prusa i3 Assembly Kit*[1], user friendly assembly
-Printer includes one direct extruder, which has the motor and nozzle attached at the same location
-Electronics run off of *Marlin Software*[2] programed into a *RepRap Arduino Mega Pololu Sheild (RAMPS)*[3] motherboard, which was used because of its open-source nature

*Figure 1: Early Printer Assembly*

## Calibration and Diagnosis of Prints

-Printed *Calibration Tests*[4] to identify best slicing and temperature settings for best quality prints

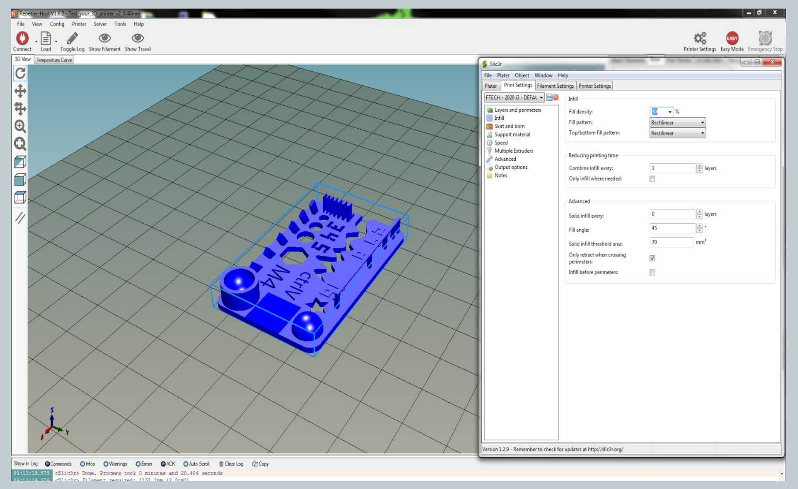
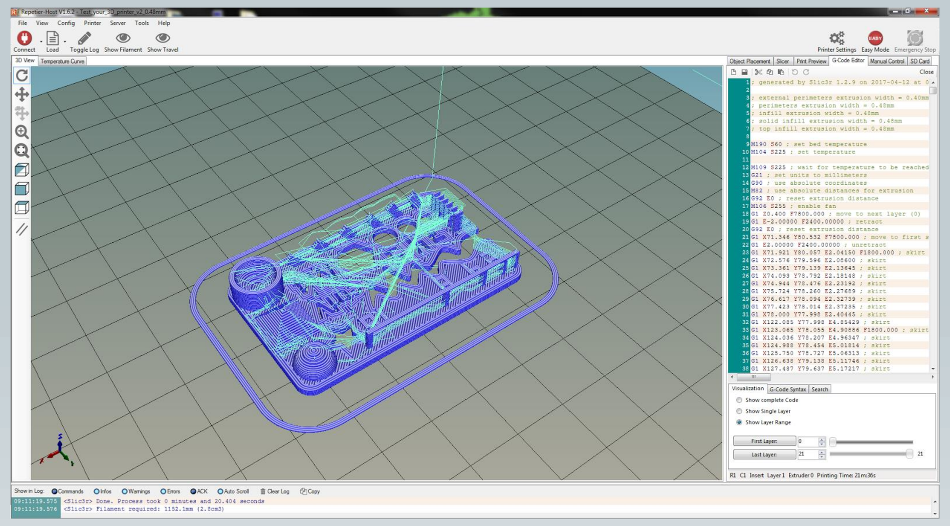


*Figure 2: Slic3r Settings*

-Settings in *Repetier*[5] and *Slic3r*[6] such as fill density, fill pattern, extruder temperature, and structural support were modified, then converted to *.Gcode files to print



-*.Gcode files show layer by layer composition of object, as well as the extruder's motion

*Figure 3: *.Gcode File of Calibration*

-Diagnosed problems such as globbing, warping, layer separation, bed leveling and ringing through *Ultimaker's Visual Guide*[7]

-Calibration needed to increase precision and intrication of specific lab tools, especially the target stick

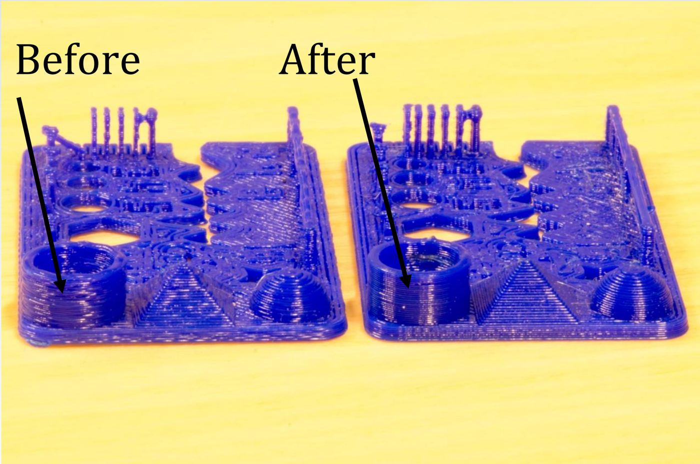



*Figure 4: Comparison of Test Prints*

## Modifications

### Aluminum Print Bed

-New bed was installed to reach 200°C, high enough to print fluoroplastics including Teflon and Kel-F (*Figure 4)*
-Bed only reached 150°C as shown in *Figure 5*, compared to most beds which can only reach 100°C

*Figure 4: Dual Extruder and New Heat Bed*

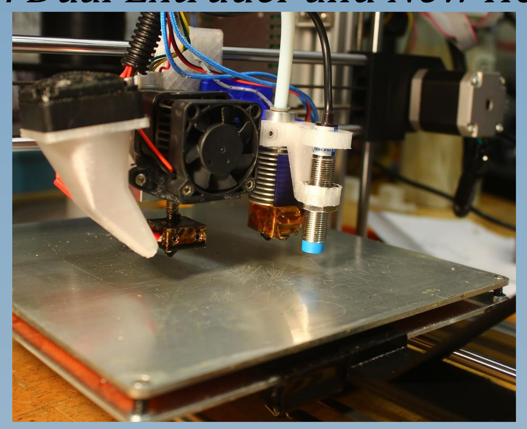
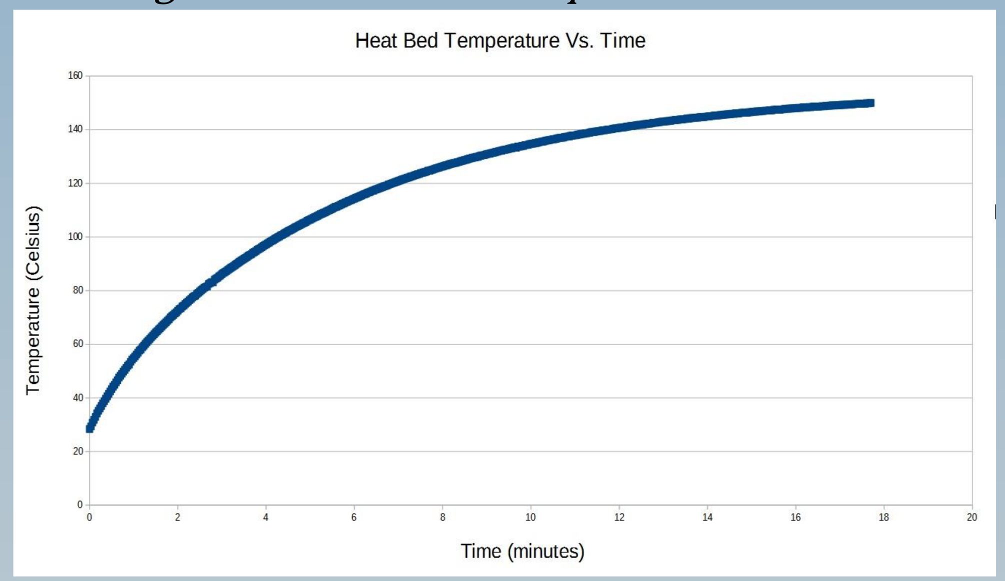


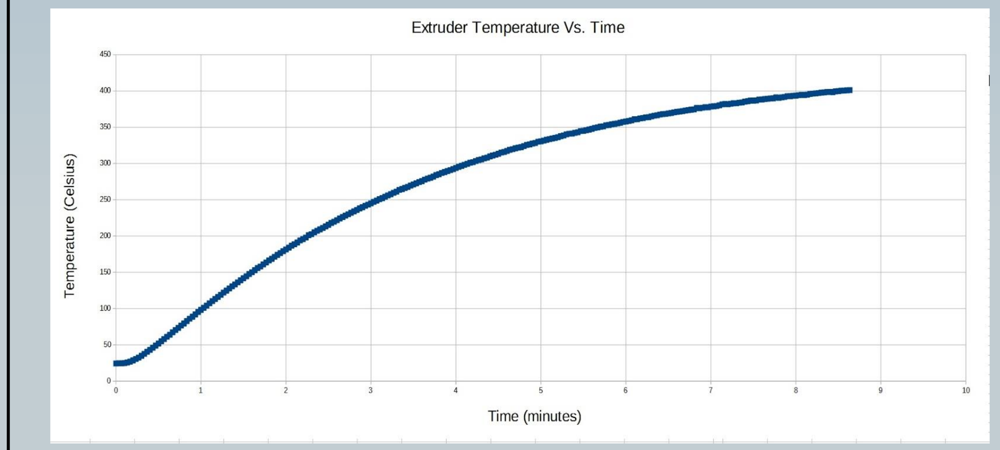
*Figure 5: Heat Bed Temperature Vs. Time*




### Dual Extrusion

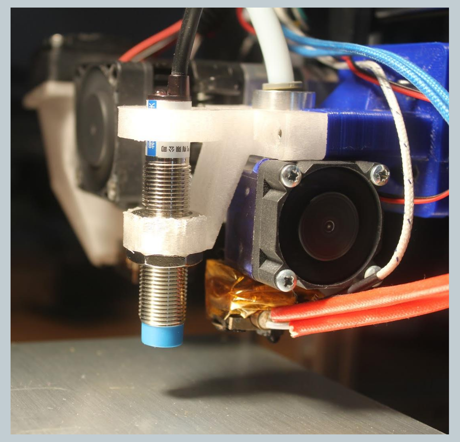
-New stainless steel bowden extruder was added to increase the maximum nozzle temperature to 400°C as shown in *Figure 6*

*Figure 6: Nozzle Temperature Vs. Time*




-Stainless steel heater block was added to the printer which included a stainless steel hobbed gear
-Stainless steel used vs. brass/copper due to a higher melting point of steel, as well as because copper is catalyse for the production of toxins such as HCl and HF, which are fluoroplastic decompensates

*Figure 7: Inductive Sensor*



### Auto Bed Leveling

-Used inductive sensor (*Figure 7)* which detects when sensor approaches metal by measuring the change in an induced B-field
-Replaced the z-axis endstop

### AutoCAD and Slic3r Software

-CAD software is used to create *.stl files of prints, turning drawings/ideas into computer models

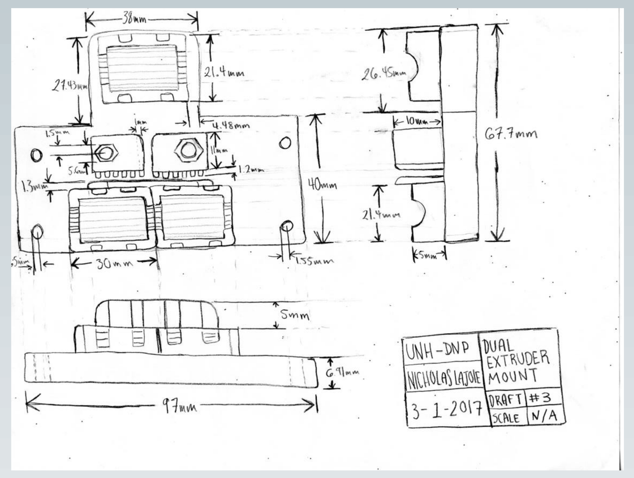


*Figure 8: Drawing of Dual Mount*

*Figure 9:* CAD rendering of Dual Mount

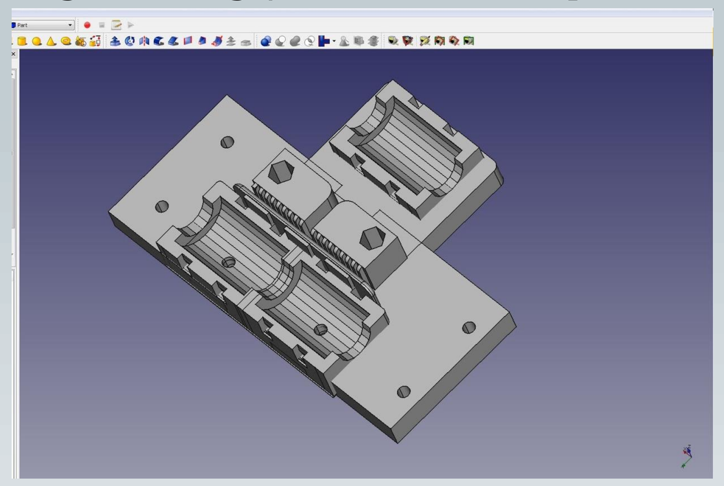


*Figure 10: 3D printed Dual Mount*

-Printer parts were modeled on CAD software and then slic3d with slic3r
-Slic3r was used to convert *.stl files into *.Gcode files, which specify the prints layer composition

## Applications

-Printed Multiple prototypes in the lab such as scaled vacuum equipment, Halbach magnets (Figure 12), and refrigerator flanges (1:1)(*Figure 11)*

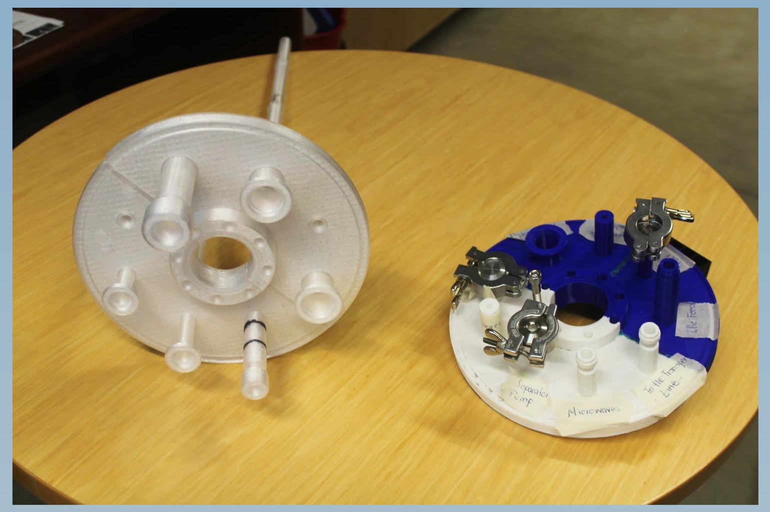
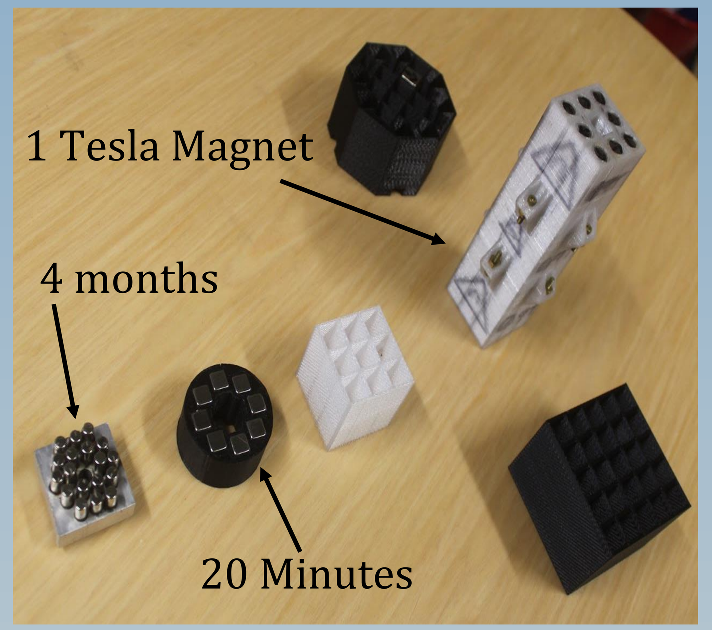


*Figure 11: Refrigerator Flanges*

*Figure 12: Halbach Magnets*



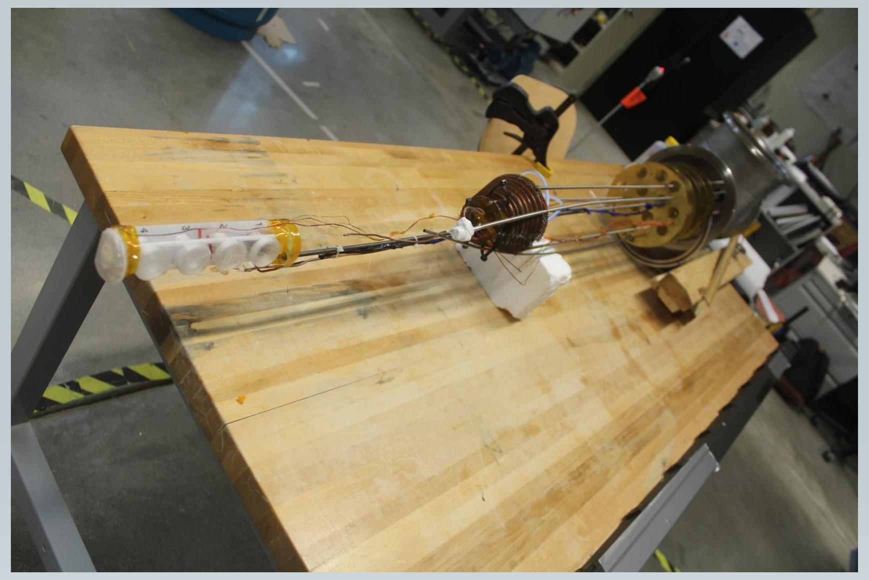

-Printed new parts for the 3D printer such as cooling units, dual extrusion mounts, camera mount, and LCD Screen mount
- Printed non-magnetic tools
- Printed and calibrated PETG, PLA, and graphene infused conducting PLA

## Future Applications

-Using KEL-F for target stick
-Creating filter for toxic fumes released
-Printer Requirements for KEL-F(Temperatures, Calibration)
-3D Circuit Boards
-3D printed Lenses

*Figure 13: PETG Target Stick*

*Figure 14:Target Stick Mounted to Refrigerator*



*References:*

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