FERMILAB-POSTER-21-101-STUDENT

Mu2e-II Target Studies: Optimizing Target Geometry and Maximizing Muon Stopping Rate

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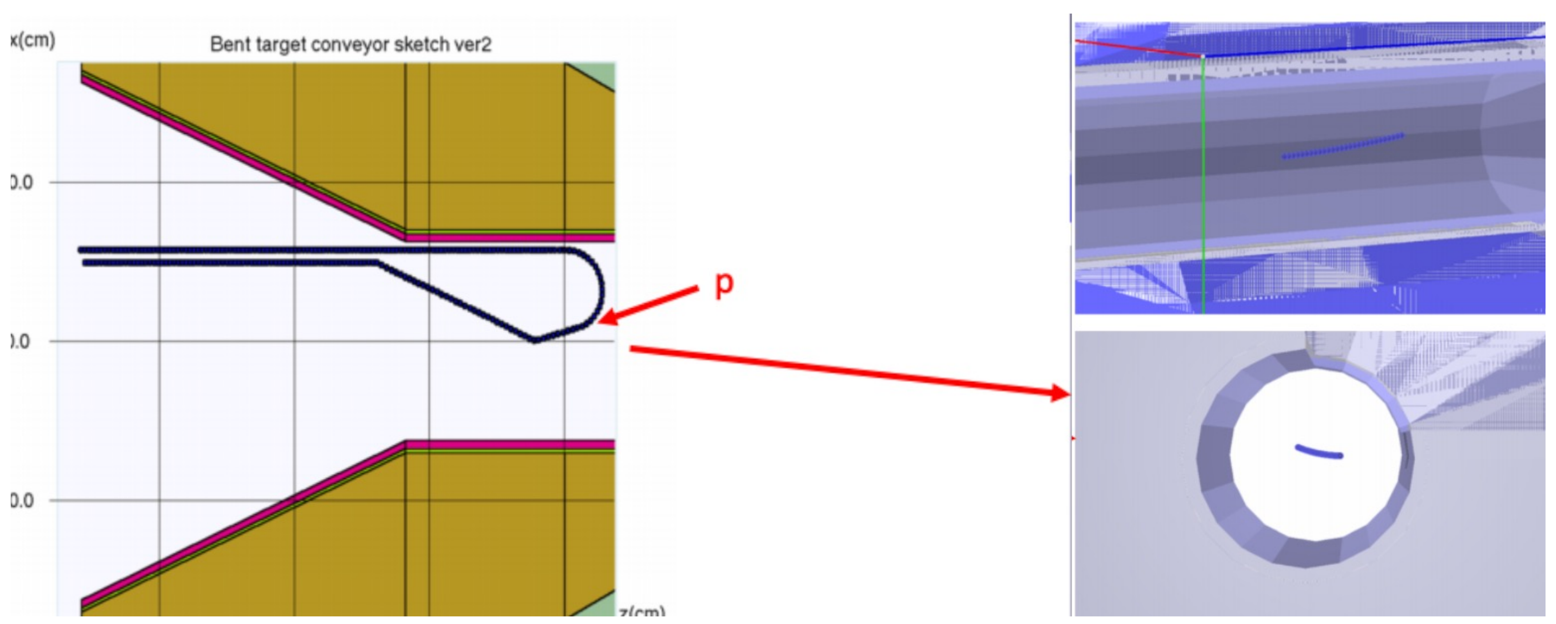
Background and Project Purposes

The Mu2e experiment will search for the charged lepton flavor violation by observing the neutrino-less conversion of a negative muon into an electron in the Coulomb field of a nucleus. We need muons in order to be used in Mu2e-II (Mu2e upgrade) experiment. Thus, target hardware (full conveyor) modeling is ongoing to estimate its effects on muon stopping rates for implementation in framework.

This target studies is for Mu2e-II (Mu2e upgrade). It is a part of LDRD experiment at Fermilab. It's aimed to optimize target geometry of the conveyor model and maximize the muon stopping rate using the standard beam code and G4beamline. The table of outcomes will contribute to this future critical experiment at Fermilab.



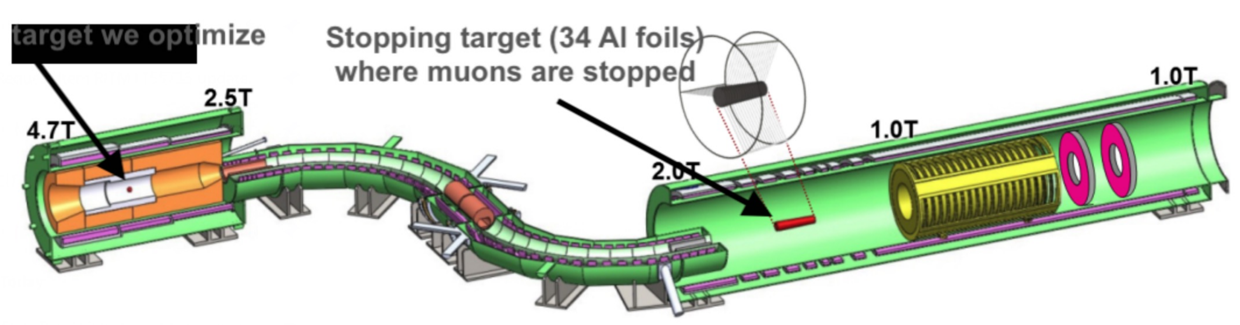
Bent Target Conveyor Sketch from LDRD

Optimizing Target Geometry Procedure

This target study is for Mu2e-II (Mu2e upgrade). In the first step, use the conveyor target model developed by LDRD and have 28 carbon spheres in the interaction region. Then, study how the shift by -20, -10, 10, and 20 cm of the target (positive direction corresponds to the muon flow direction) affects the stopping rates.

In details, for each target position, to align the target spheres along proton trajectories precisely, the following steps were executed:

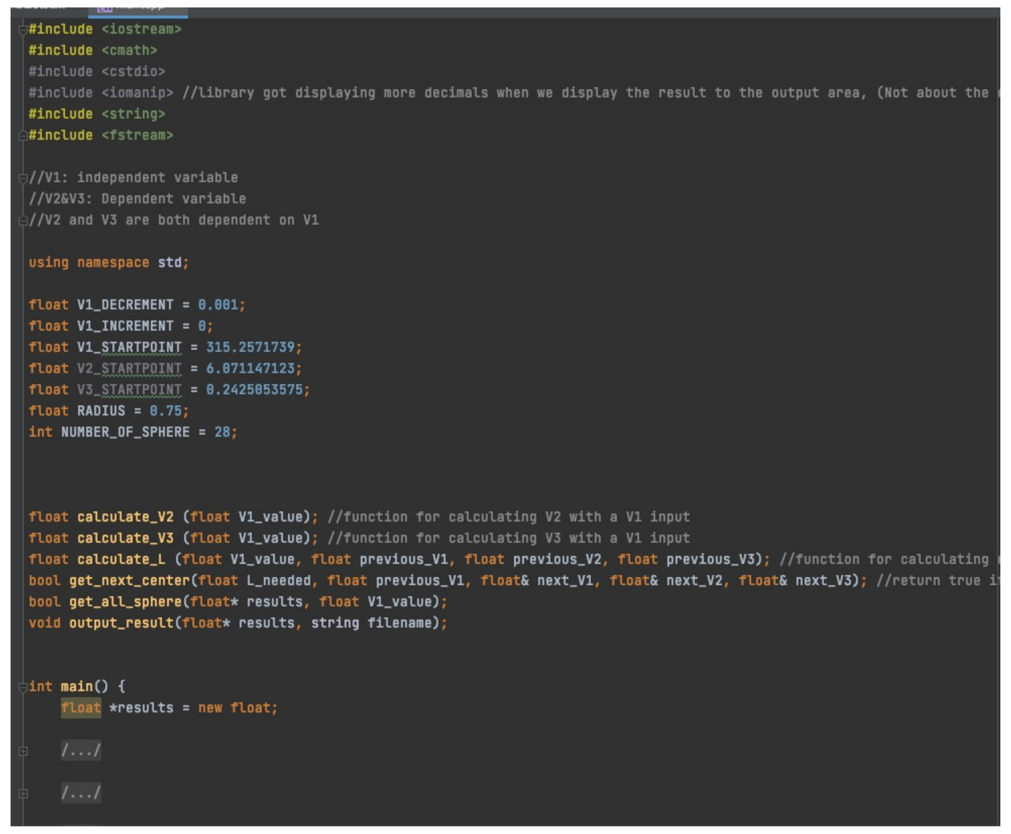
1) Obtained proton trajectories in a tabular form from simulations.
2) Fitted the trajectories with 2nd and 3rd order polynomials.
3) Used my developed C++ code to calculate coordinates for the centers of the spheres with constant gaps = 0.01 cm between them.



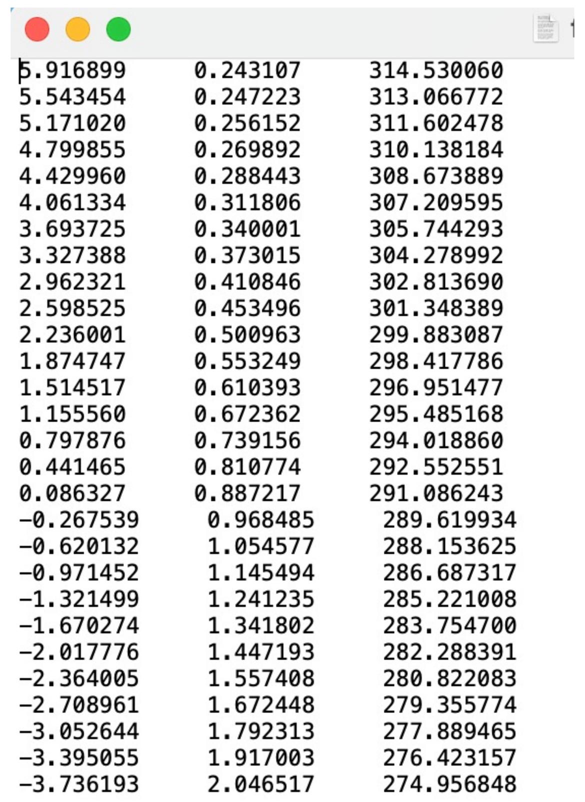
Entire Stopping Target Setup Plot

Sphere Obtaining Programing Project

- This C++ program is aimed to calculate the center of spheres coordinate. It's capable after the 2nd or 3rd order polynomial equation of the trajectory curve is obtained. The program was designed with flexibility.
- Input Data needed: The polynomial algebraic equation for the 2 dependent variable using the 3rd coordinate as independent variable. The starting point of the trajectory, and the radius of the balls.
- Output of this program: The output will be in a txt file. The 3 coordinate of each of the balls will be listed and separated by space. The coordinates of each balls are in separate lines.



```
#include <iostream>
#include <cmath>
#include <cstdio>
#include <iomanip> //library got displaying more decimals when we display the result to the output area, (Not about the
#include <string>
#include <fstream>

//V1: independent variable
//V2&V3: Dependent variable
//V2 and V3 are both dependent on V1

using namespace std;

float V1_DECREMENT = 0.001;
float V1_INCREMENT = 0;
float V1_STARTPOINT = 315.2571739;
float V2_STARTPOINT = 6.071147123;
float V3_STARTPOINT = 0.2425053575;
float RADIUS = 0.75;
int NUMBER_OF_SPHERE = 28;


float calculate_V2 (float V1_value); //function for calculating V2 with a V1 input
float calculate_V3 (float V1_value); //function for calculating V3 with a V1 input
float calculate_L (float V1_value, float previous_V1, float previous_V2, float previous_V3); //function for calculating
bool get_next_center(float L_needed, float previous_V1, float& next_V1, float& next_V2, float& next_V3); //return true i
bool get_all_sphere(float* results, float V1_value);
void output_result(float* results, string filename);


int main() {
    float *results = new float;

    /.../

    /.../
```



5.916899	0.243107	314.530060
5.543454	0.247223	313.066772
5.171020	0.256152	311.602478
4.799855	0.269892	310.138184
4.429960	0.288443	308.673889
4.061334	0.311806	307.209595
3.693725	0.340001	305.744293
3.327388	0.373015	304.278992
2.962321	0.410846	302.813690
2.598525	0.453496	301.348389
2.236001	0.500963	299.883087
1.874747	0.553249	298.417786
1.514517	0.610393	296.951477
1.155560	0.672362	295.485168
0.797876	0.739156	294.018860
0.441465	0.810774	292.552551
0.086327	0.887217	291.086243
-0.267539	0.968485	289.619934
-0.620132	1.054577	288.153625
-0.971452	1.145494	286.687317
-1.321499	1.241235	285.221008
-1.670274	1.341802	283.754700
-2.017776	1.447193	282.288391
-2.364005	1.557408	280.822083
-2.708961	1.672448	279.355774
-3.052644	1.792313	277.889465
-3.395055	1.917003	276.423157
-3.736193	2.046517	274.956848

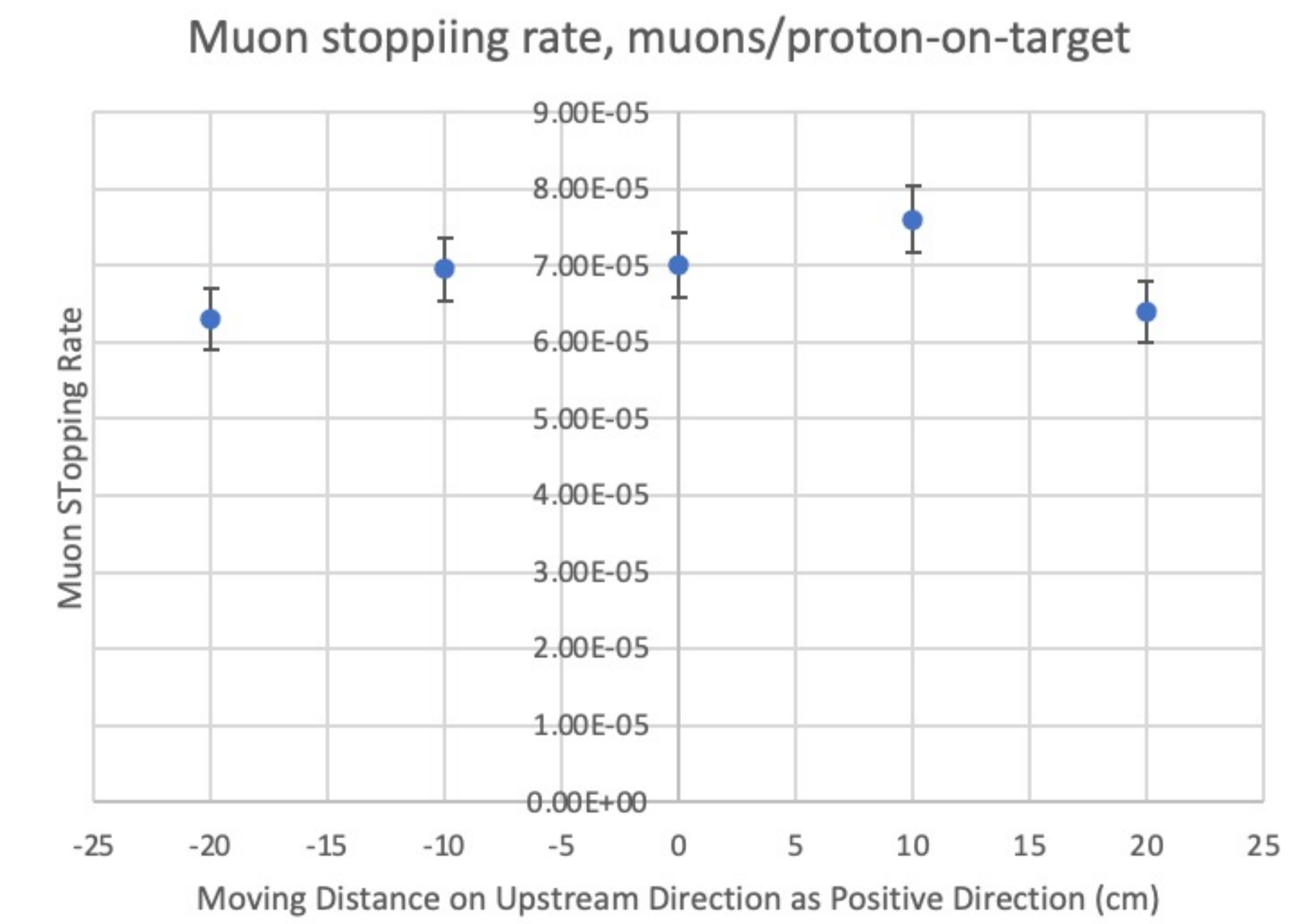
Left - Part of the Sphere Obtaining Coding project
Right – Sample of output of the Coding Project

Summary Result and Conclusion

The center of spheres were inputted in G4beamline and the stopping rates were obtained with G4beamline.

Shift, cm	st.mu	d st.mu
-20	6.30E-05	3.97E-06
-10	6.95E-05	4.17E-06
0	7.01E-05	4.20E-06
10	7.60E-05	4.36E-06
20	6.40E-05	4.00E-06

Muon Stopping Rate and Uncertainty in Different Shifting Direction and Distance



Muon Stopping Rate Result in Chart

From the data, we can know shifting the target upward 10cm can give slightly better result, but the difference between rates is not greater than the uncertainty of the results. Thus, within the statistical uncertainty, the rates are indistinguishable.

In conclusion, there are no significant advantages in moving the target. The effect of shifting the target 10 cm upstream on the muon stopping rate requires more studies.

Acknowledgment

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