Documentation and Usage of Sieve Hole Automatic Selection Script

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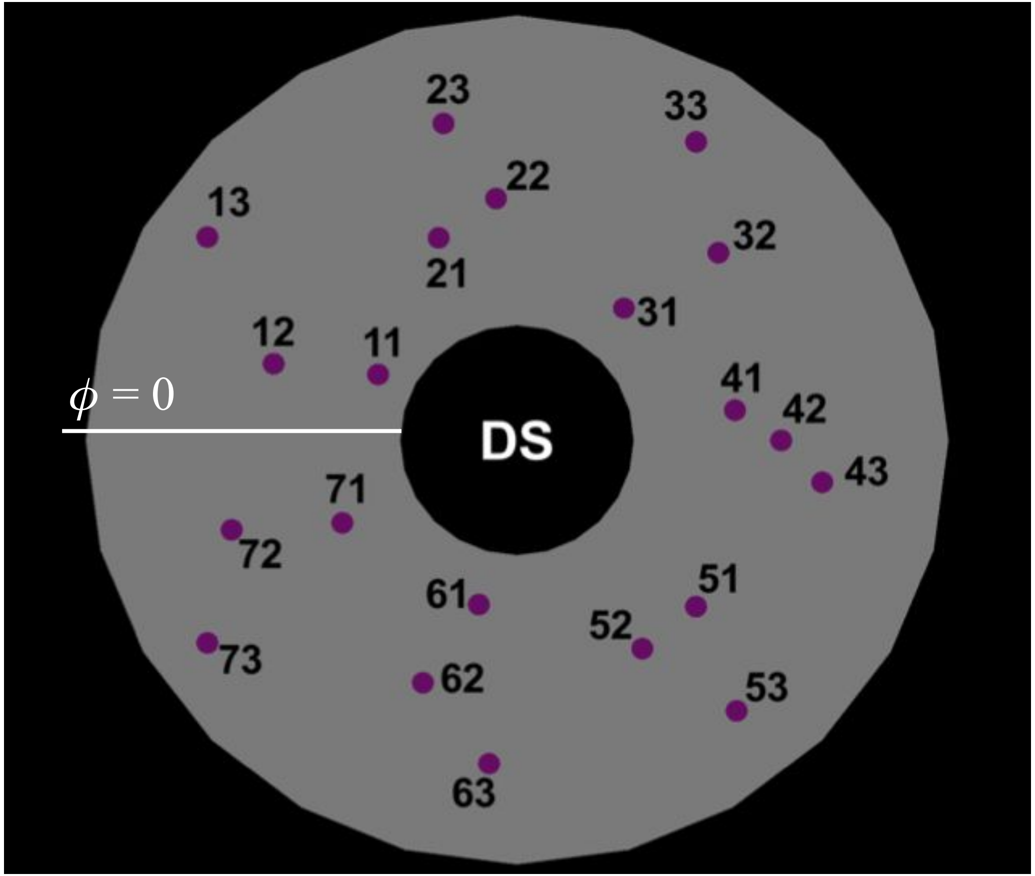
Introduction

The original way of selecting sieve hole images was to manually draw a polygon around the data points corresponding to each sieve hole in an r vs phi plot on the first GEM layer. This method, while effective, was especially tedious when faced with hundreds of configurations that each have 21 sieve hole images to select.

We need a method to automatically select sieve hole images on the GEMs that requires minimal known information about the location of the images. Since the positions of the images may differ from the ideal locations when we adjust the magnetic field, we don’t want to rely heavily on input information.

The script(s) described in this documentation allows us to automatically select individual sieve hole images and send their information to separate CSV files for analysis.

Known Location Information



Hole ID	Local Phi Offset [degrees]	Global Central Phi Location [radians]
11	0	0.449
12	-8	0.309
13	8	0.588
21	-8	1.207
22	8	1.486
23	0	1.346
31	0	2.244
32	8	2.384
33	-8	2.104
41	-8	3.002
42	0	3.142
43	8	3.281
51	-8	3.900
52	8	4.179
53	0	4.039
61	0	4.937
62	8	5.076
63	-8	4.797
71	0	5.834
72	8	5.974
73	-8	5.695

Define Azimuthal Search Regions

Hole ID	Local Phi Offset [degrees]	Global Central Phi Location [radians]	Lower Phi Bound [radians]	Upper Phi Bound [radians]	Phi Range [radians]
11	0	0.449	0.344	0.598	0.254
12	-8	0.309	0.000	0.344	0.344
13	8	0.588	0.598	0.898	0.299
21	-8	1.207	0.898	1.272	0.374
22	8	1.486	1.451	1.795	0.344
23	0	1.346	1.272	1.451	0.180
31	0	2.244	2.094	2.394	0.299
32	8	2.384	2.394	2.693	0.299
33	-8	2.104	1.795	2.094	0.299
41	-8	3.002	2.693	3.040	0.347
42	0	3.142	3.040	3.291	0.251
43	8	3.281	3.291	3.590	0.299
51	-8	3.900	3.590	3.964	0.374
52	8	4.179	4.136	4.488	0.352
53	0	4.039	3.964	4.136	0.172
61	0	4.937	4.787	5.049	0.262
62	8	5.076	5.049	5.386	0.337
63	-8	4.797	4.488	4.787	0.299
71	0	5.834	5.685	5.984	0.299
72	8	5.974	5.984	6.283	0.299
73	-8	5.695	5.386	5.685	0.299

Note that $2\pi/21$ is 0.299 radians.

Holes placed at the local center of their sectors have on average a smaller phi search region compared to holes on the edges of their sectors. This is due to azimuthal defocusing.

Exact ranges were found empirically from previous simulations (assumption).

Basic Script Functionality

The script reads in a root file and a value for the sieve rotation.

- It is important that the root file be named properly because the script searches the name of the root file to define important information about the configuration of the simulation.
    - The beam energy must be included in the form “Pass#” where # is 1, 2, 3, 4, or 5.
    - The target used must be included, and the valid options are: “Optics1”, “Optics2”, “Optics3”, or “LH2”.
    - The magnetic field map used must be included. Currently the valid options are: “Symmetric”, “DipolePoint5RandSC23”, “Dipole3SameSC23”, “A2mm_inward”, “A1mm_inward”, “A1mm_outward”, “A2mm_outward”, “A3mm_outward”, or “A4mm_outward”.
    - More field map options can be added as they are created.
- The sieve rotation is in increments of how many sectors was the sieve rotated in azimuth, and the input value should be a double equal to the number of degrees for each rotation.
    - The possible options for sieve rotation in degrees are: 0.0 (0 sector rotations), 51.0 (1 sector rotation), 103.0 (2 sector rotations), 154.0 (3 sector rotations), 206.0 (4 sector rotations), 257.0 (5 sector rotations), or 309.0 (6 sector rotations).
- An example of execution with proper input would be:

GenHoleCSV(“Pass2_Optics1_A1mm_inward_elasticC12_1M.root”,0.0)

Basic Script Functionality (Cont.)

The script will first used the sieve rotation to define the azimuthal search regions for each hole. These regions stay qualitatively the same through sieve rotations, but they each have an overall shift equal to the azimuthal rotation of the sieve.

Next, the script will read the root file name to define the beam pass, target, and field map, and it will print out these values.

The script also defines a path to the output directory. This will need to be adjusted for new users. It will also print out this path name.

Next, the script will define 2D r vs phi and 1D r histograms depending on the beam pass. The radial location of particles scattered from the sieve varies hugely between different beam energies, but the magnetic field is designed to send particles with similar energies to a small, known region in r, so we can reasonably make radial search regions sized 200-400mm.

Basic Script Functionality (Cont.)

Next, the script assigns each event to a sieve hole based on it’s azimuthal location on the GEM.

Each event is then sent to 1D histograms corresponding to its sieve hole index. Histograms of r, r’, phi, and phi’ are filled.

All events are sent to 2D r vs phi, r vs r’, and phi vs phi’ histograms.

Next, we look at information from each sieve hole. If there is no information for a given sieve hole (like for holes 11, 31, 61, and 71 from Pass1 data), then we move on to the next hole.

For each viable hole, a CSV file is created with the following columns: tg_th, tg_ph, tg_p, tg_vz, sieve_r, gem_r, r_prime, gem_ph, phi_prime.

Detail Fitting - Radial Hits

We now have a good guess of which events correlate to which sieve holes, but we can fit to the data we have to cut out outliers and radiative tails.

In order to make a tight cut on events to exclude any particles that are part of the radiative tail, we can apply an energy cut. This will only keep particles with energy that differ from the beam energy by less than 2MeV. This cut is optional, and going forward, we will assume it is NOT made and we are looking at all energies.

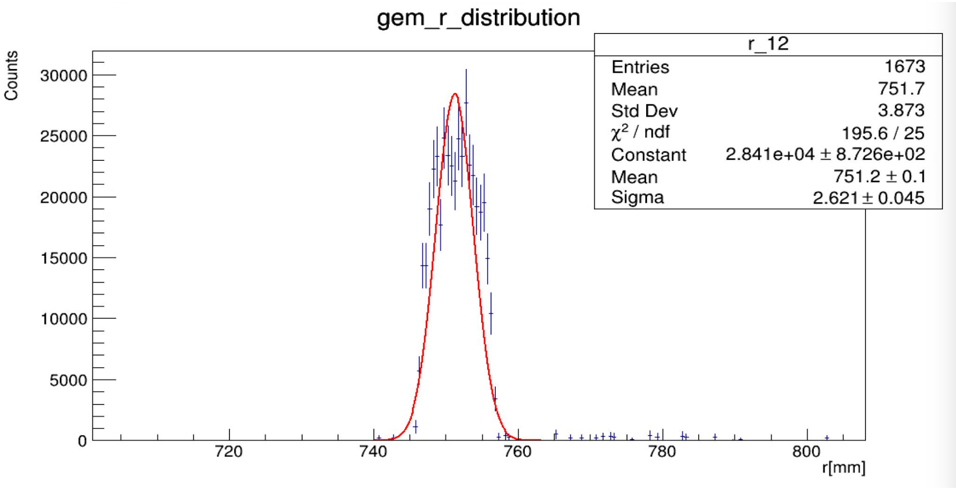
Using the mean and standard deviation of the hole data, we can define a radial range of interest. This script looks at (r_mean - 2.5 r_std, r_mean + 1.0 r_std) and defines a gaussian function that will fit to the data in this region.

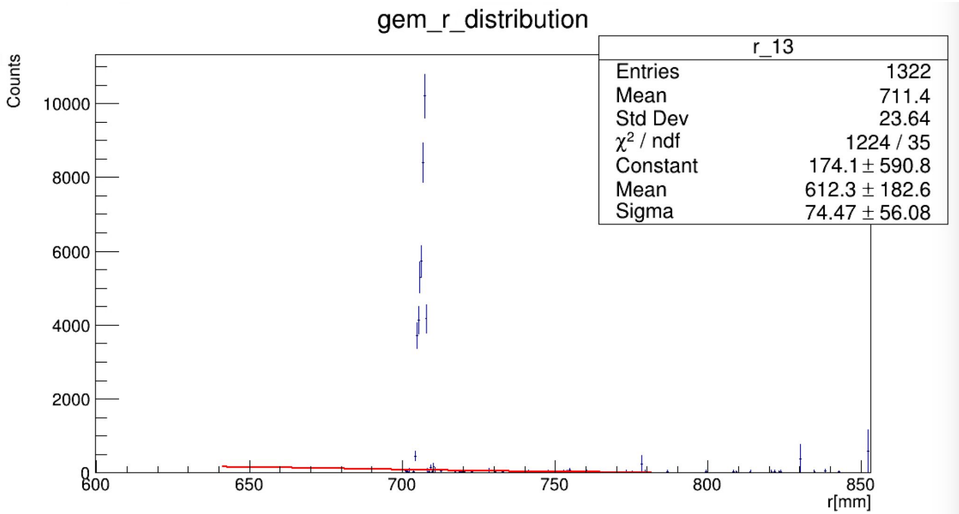
Then, the script fits the gaussian function to the data. It then iteratively fits 3 more times, using the previous fit's parameters as a range to fit over: (gaus_mean +/- 2.0 gaus_std).

The scripts fits to r' in the same way.

Detail Fitting - Radial Hits (Cont.)

Root sometimes fails to fit a gaussian to the radial data. Compare the following two plots:





The easiest way to identify an improper fitting is by looking at the sigma of the fit. The script checks if the sigma is <=20.0, and if it's not then a range on r of 600mm to 1200mm is used. The ranges on phi, r', and phi' are unaffected.

Detail Fitting - Azimuthal Hits

Because we initial defined azimuthal regions for each hole, the script uses the bounds on these regions to define a gaussian to fit on the phi data.

Alternatively, phi’ is fit within a similarly defined region as with r and r’, but we do not iterate over its fit.

All final sieve hole images then have a gaussian fit for r, r’, phi, and phi’.

Now, for each hole we define an upper and lower bound on each of these variables that corresponds to 3.0 sigma away from the mean (based on the gaussian fits).

Filling Histograms and CSV Files

Finally, we loop through all the events and check in they fall within these upper and lower bounds.

For each sieve hole, we make an r vs phi, r’ vs phi, and phi’ vs phi histogram as well as a CSV file with only the events that fall within the defined bounds.

An example of the name of a CSV file is:

output/A3mm_outward_Pass1_Optics2_2secRot_31.csv

All of these histograms as well as gaussian fits are written to a root file.

An example of this root file is:

output/Symmetric_Pass3_Optics1_4secRot_plots.root

Resources

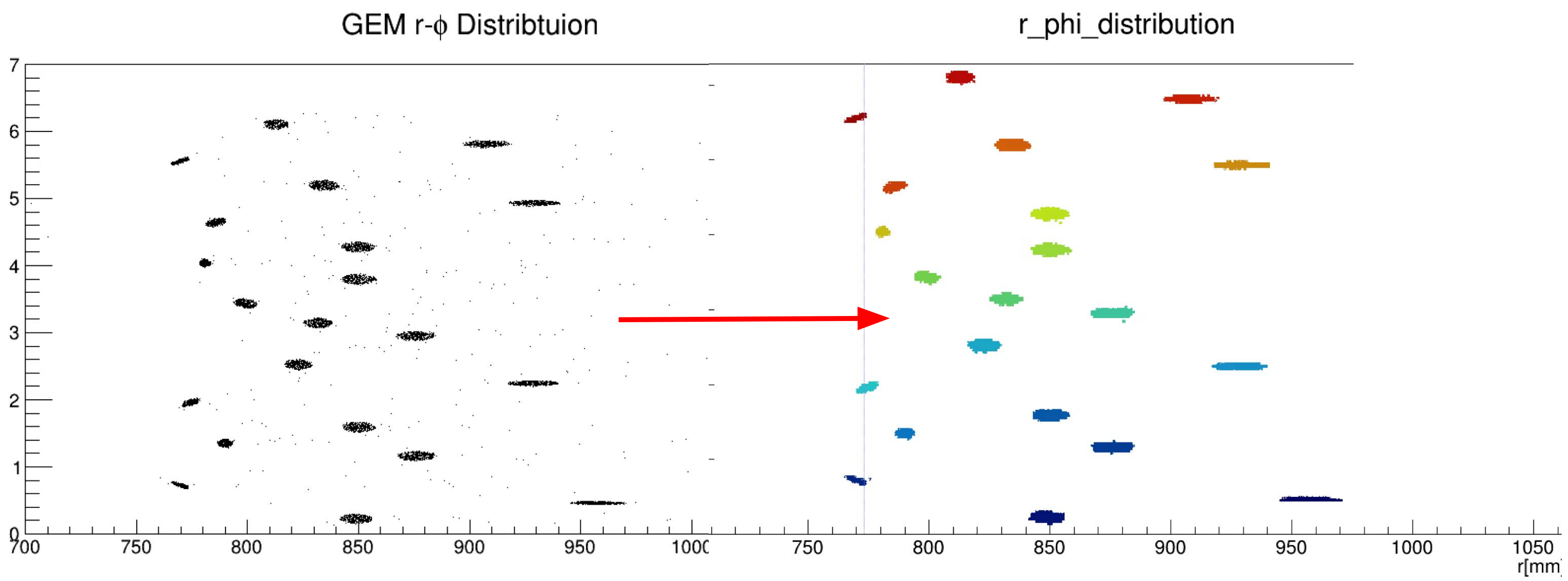
Original script made by Vassu Doomra [1]

Edited script made by Kate Evans [2]

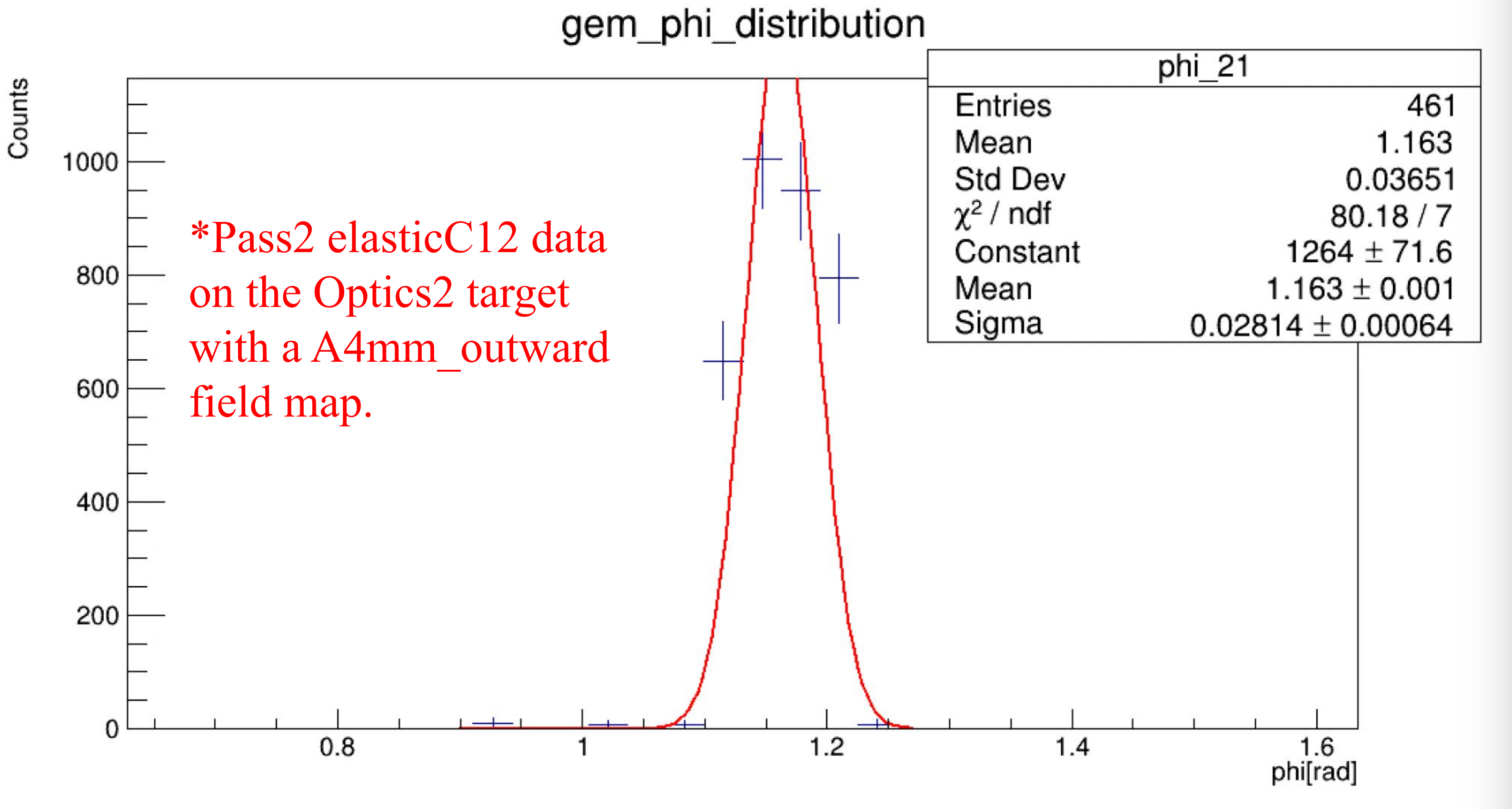
Root files with script results on the farm:

- /volatile/halla/moller12gev/ktevans1/rootfiles2024/MagFieldStudy/Symmetric/output/Symmetric_p1_Optics3_0secRot_plots.root
- /volatile/halla/moller12gev/ktevans1/rootfiles2024/MagFieldStudy/A2mm_outward/output/A2mm_outward_p5_LH2_0secRot_plots.root
- /volatile/halla/moller12gev/ktevans1/rootfiles2024/MagFieldStudy/A4mm_outward/output/A4mm_outward_p2_Optics2_0secRot_plots.root

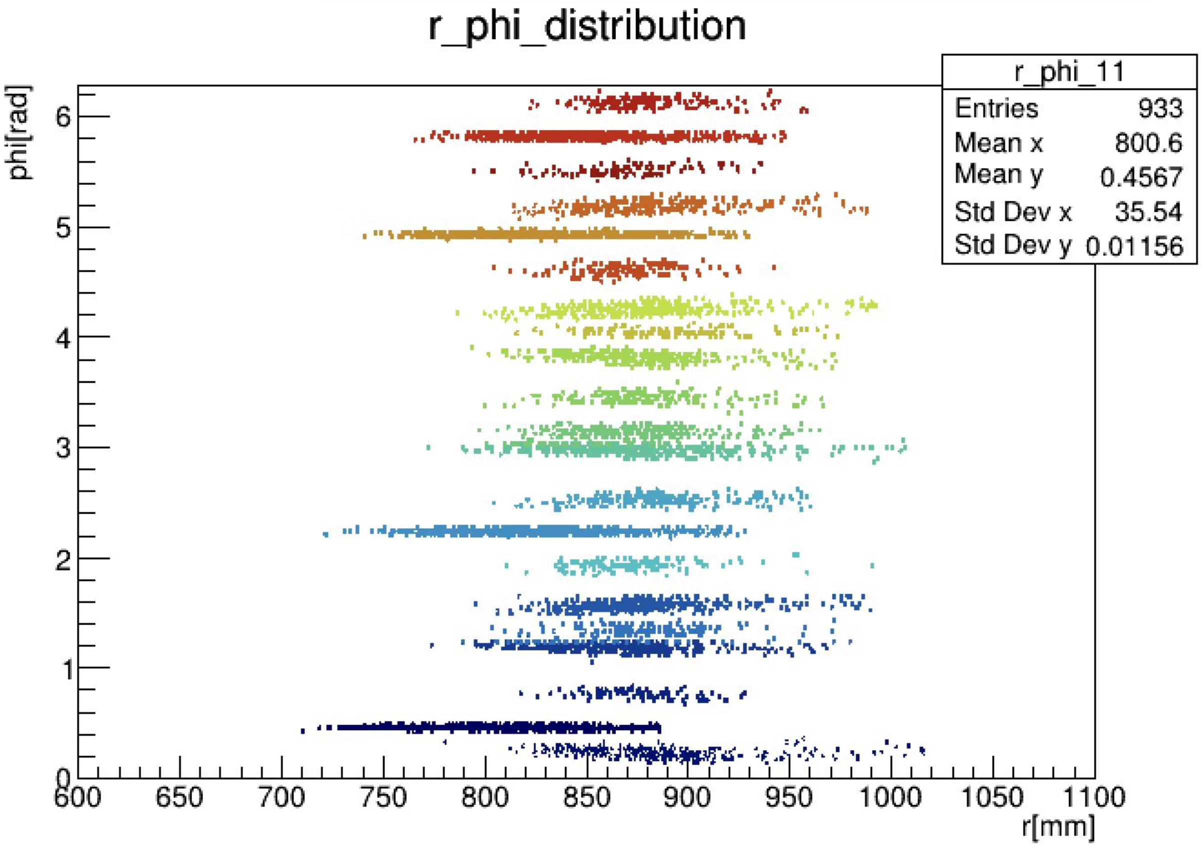
Example Results



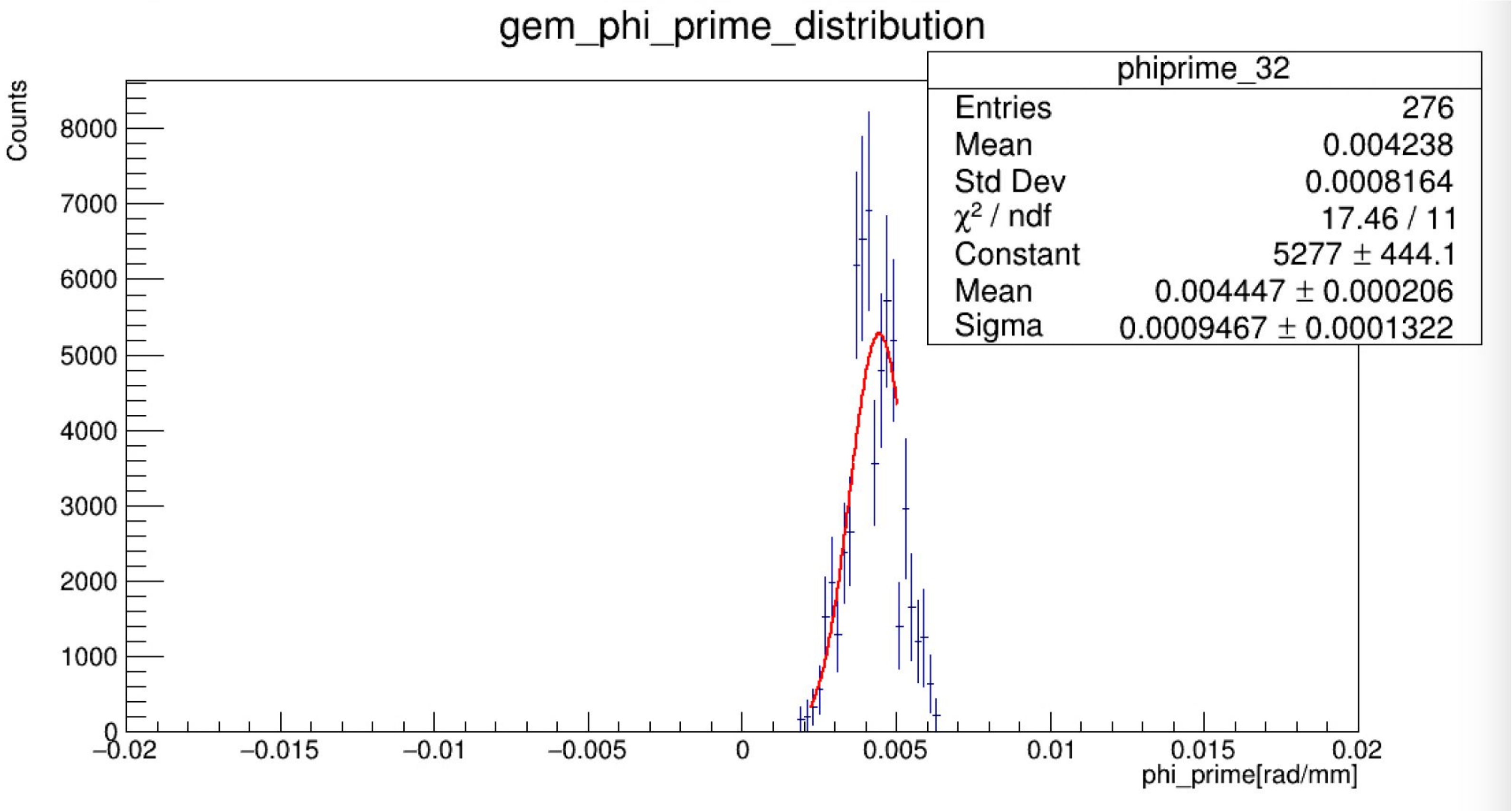
Pass2 elasticC12 data on the Optics2 target with a A4mm_outward field map - before and after automatic selection.



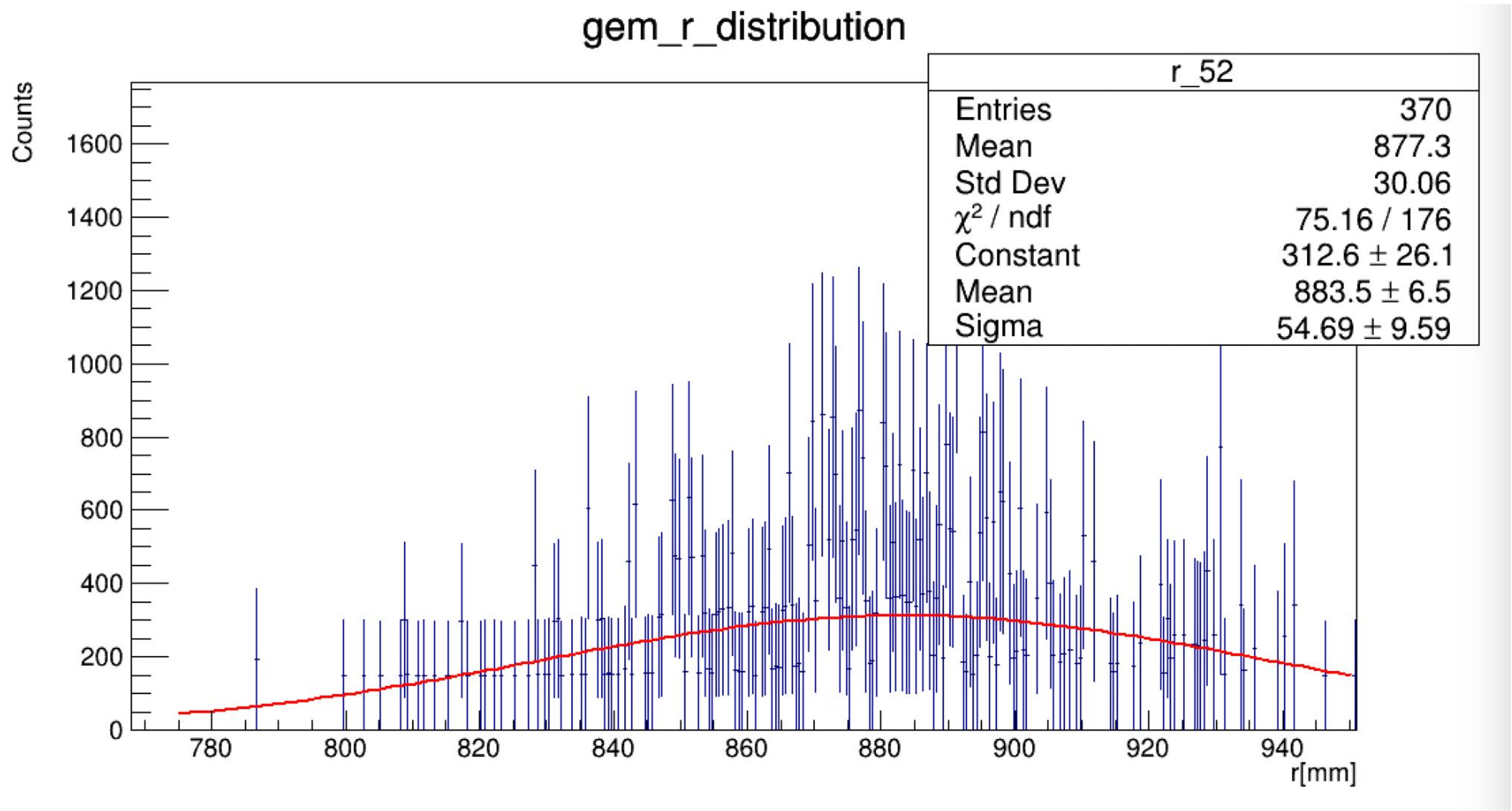
Distribution of phi hits from hole 21 with a gaussian fit. The mean and sigma in the stat box are used to define the bounds within which histograms and CSV files are made.



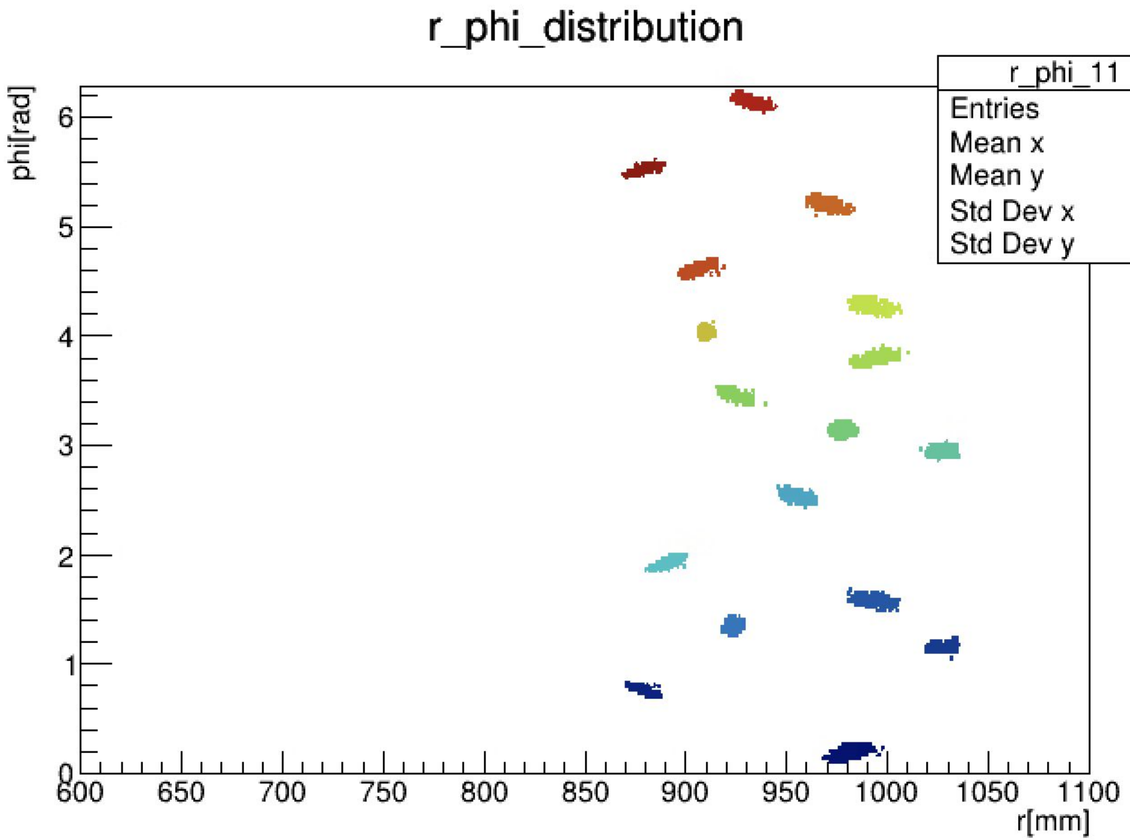
Pass5 moller data on the LH2 target with a A2mm_outward field map. Each color corresponds to data from a different sieve hole.



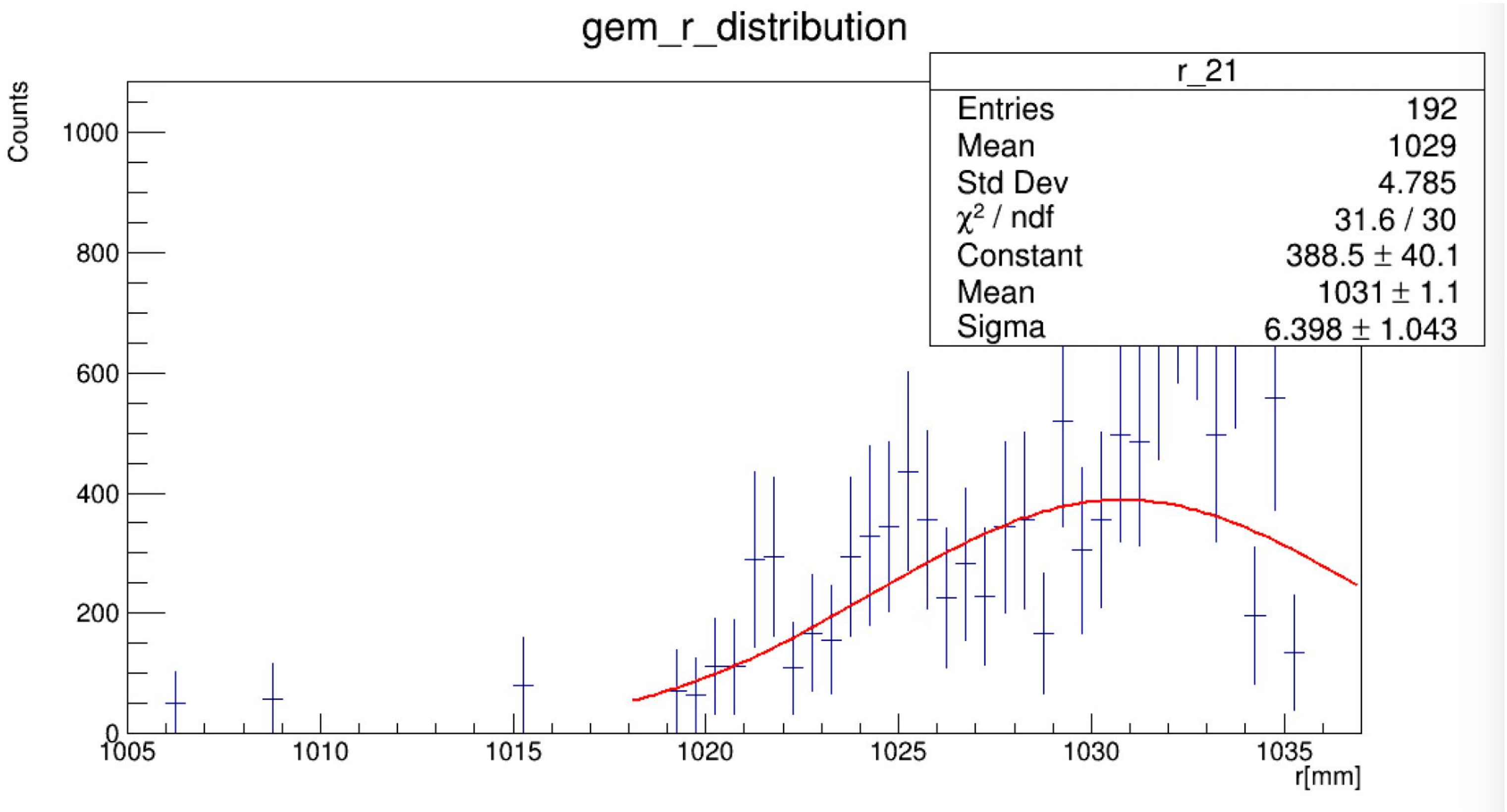
Pass5 moller data on the LH2 target with a A2mm_outward field map.



Pass5 moller data on the LH2 target with a A2mm_outward field map.



Pass1 elasticC12 data on the Optics3 target with a Symmetric field map. Each color corresponds to data from a different sieve hole. As expected, holes 11, 31, 61, and 71 are missing.



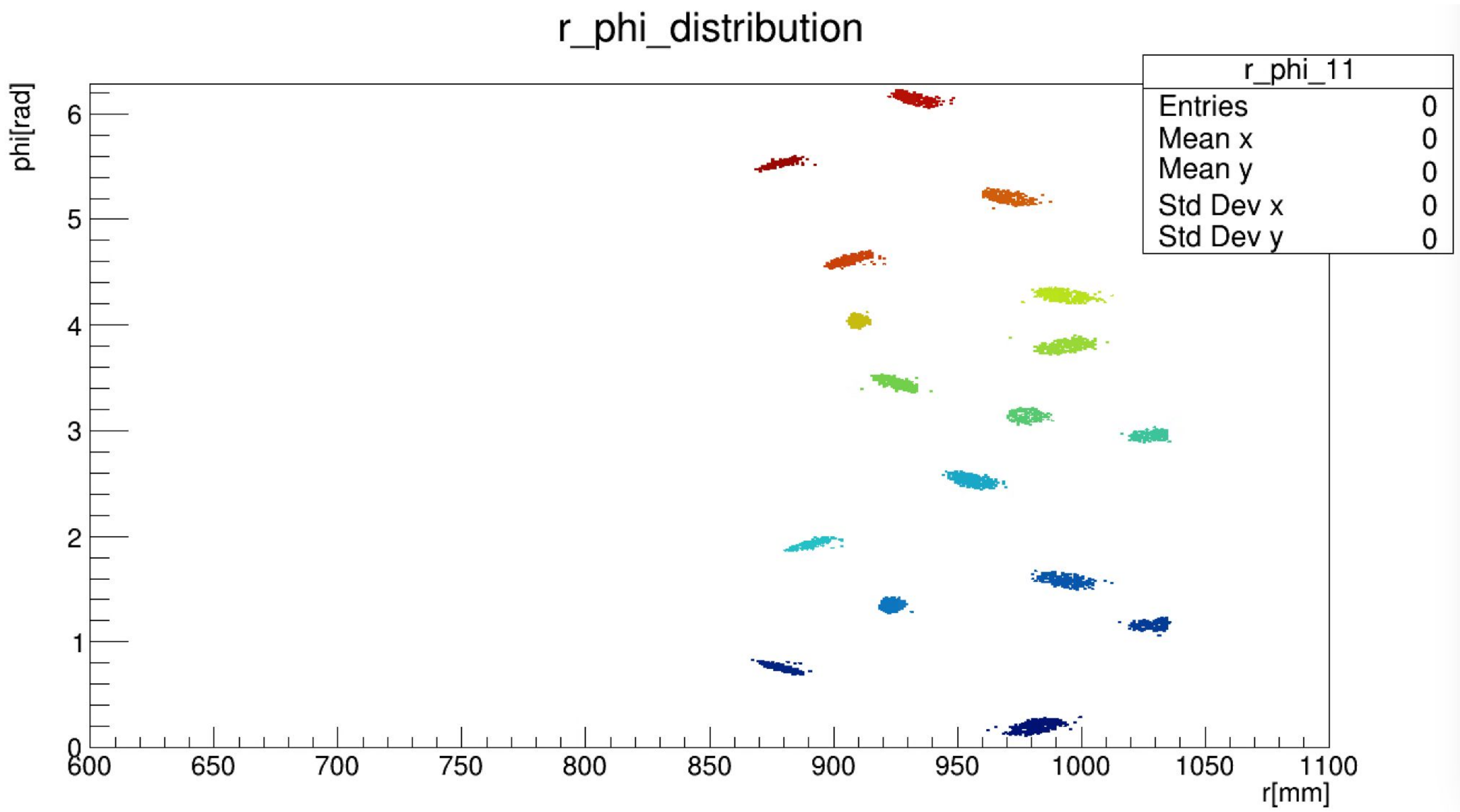
Pass1 elasticC12 data on the Optics3 target with a Symmetric field map. Hole 21 is slightly cut off in r, and you can see that the distribution of data points does not extend to the right as much.

Widen Search Regions

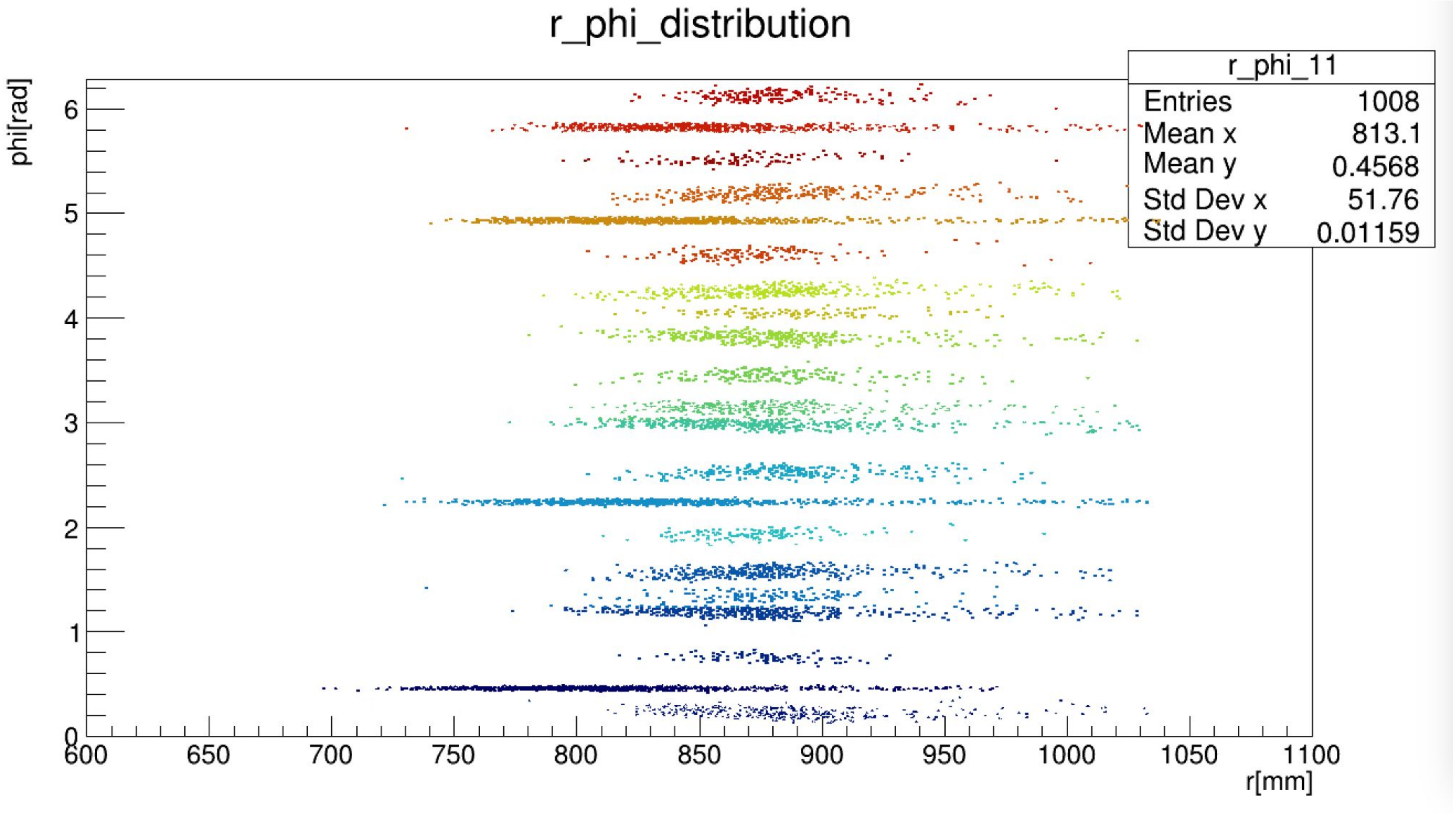
Subtle Changes to Script

1. The binning on the 2D r vs phi plots for each hole was increased
2. All gaussians are now plotted over a wider range: mean_data +/- 3.0 * RMS_data
3. Upper and lower bounds on our variables found from gaussian fits are all widened to include 3 sigma

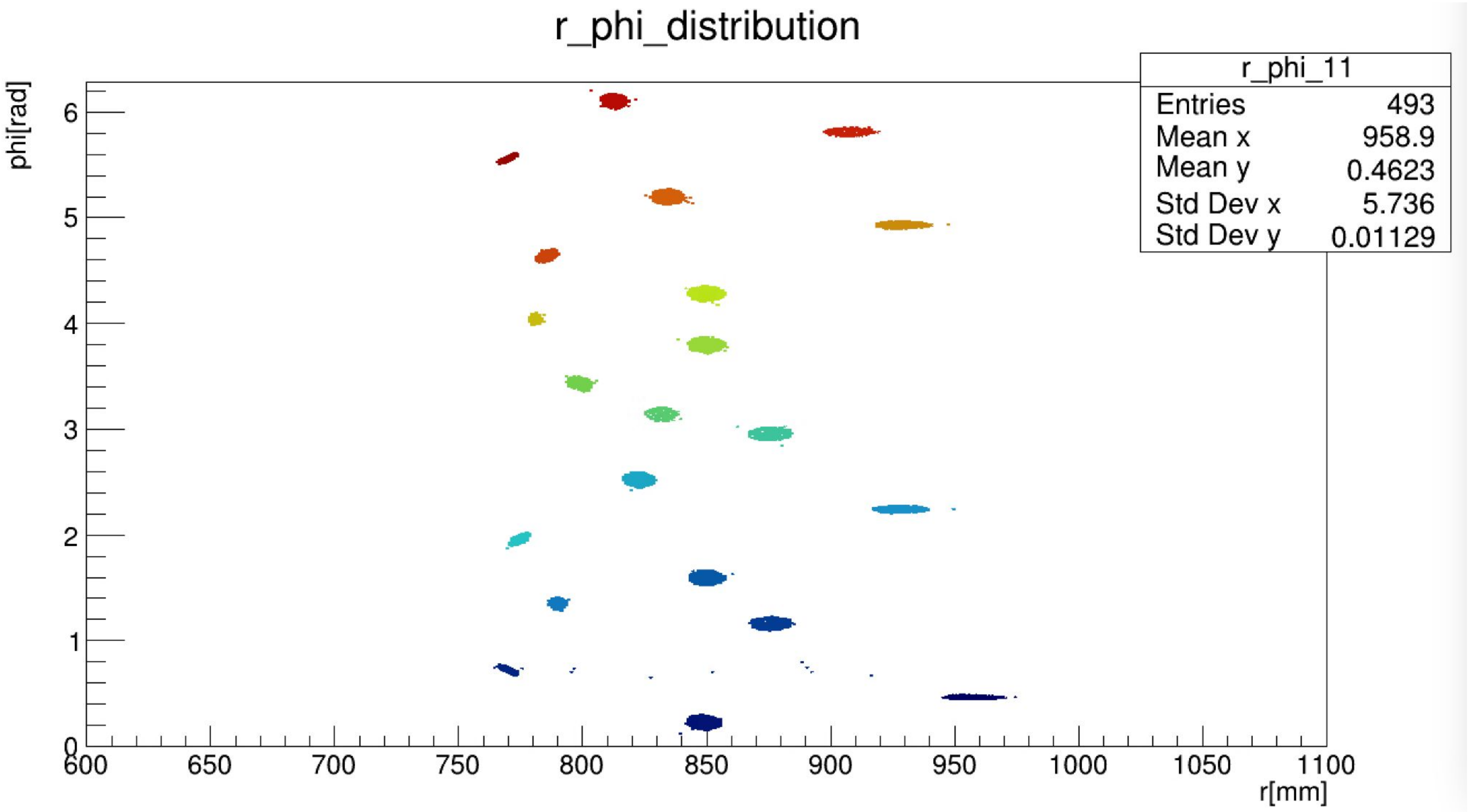
This will mean that our CSV files include some events from the radiative tails, but because the magnetic field study fits a confidence ellipse to the CSV data anyway, it is better to make wider selections on each hole initially.



Pass1 elasticC12 data on the Optics3 target with a Symmetric field map. Each color corresponds to data from a different sieve hole.



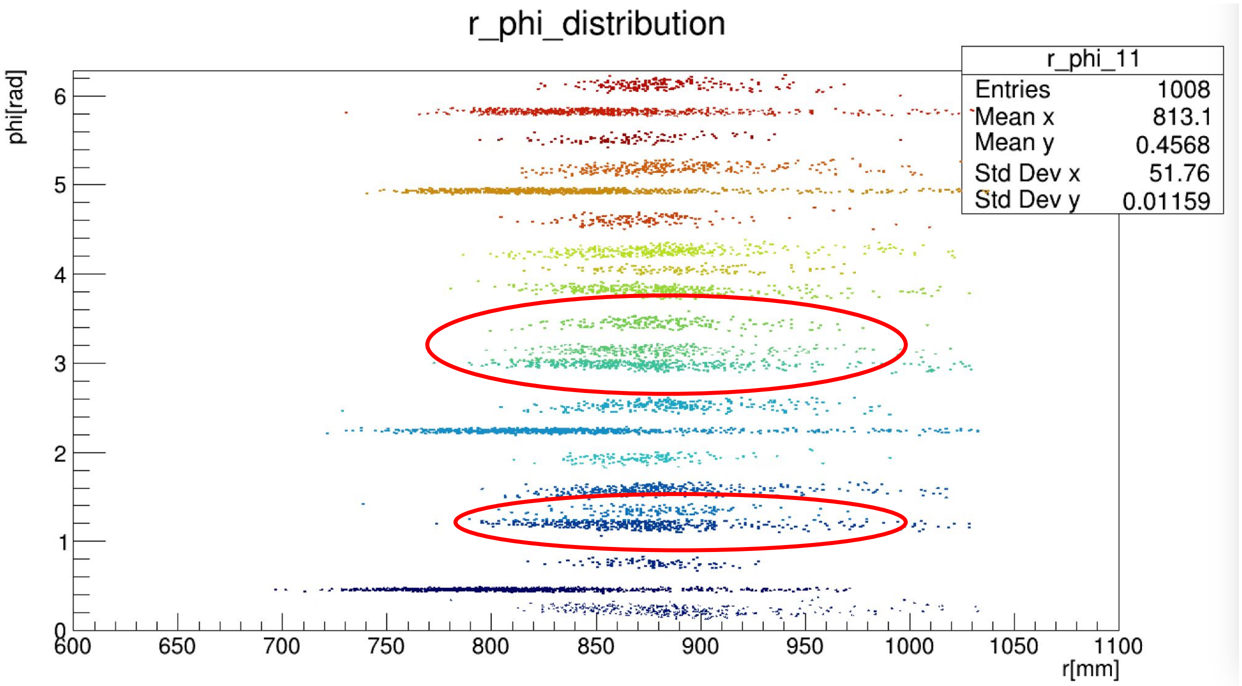
Pass5 moller data on the LH2 target with a A2mm_outward field map. Each color corresponds to data from a different sieve hole.

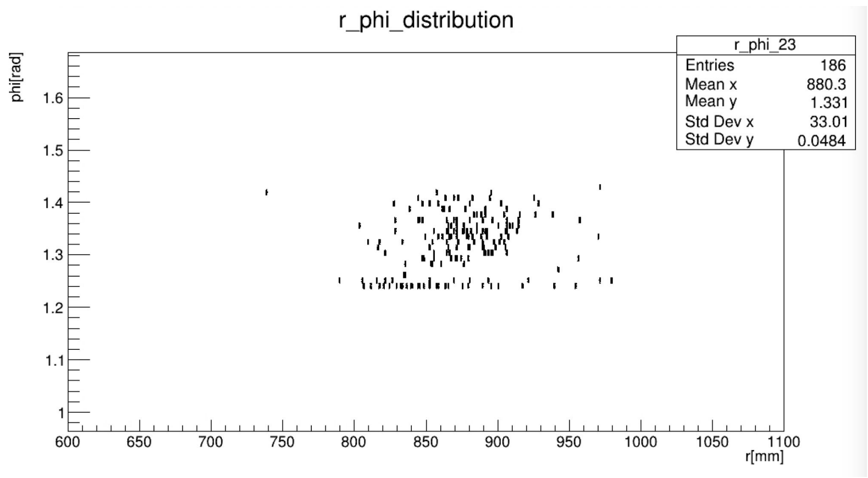


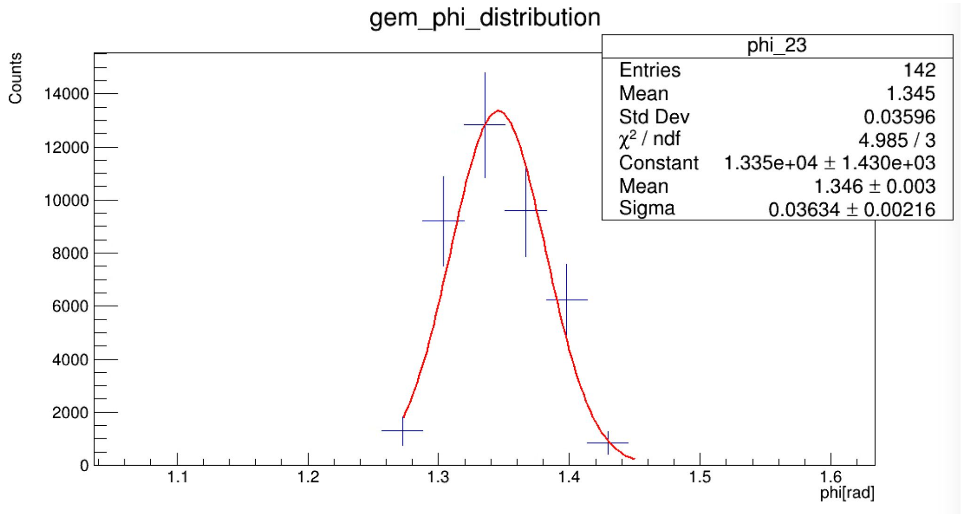
Pass2 elasticC12 data on the Optics2 target with a A4mm_outward field map.

Messy holes in Pass 5

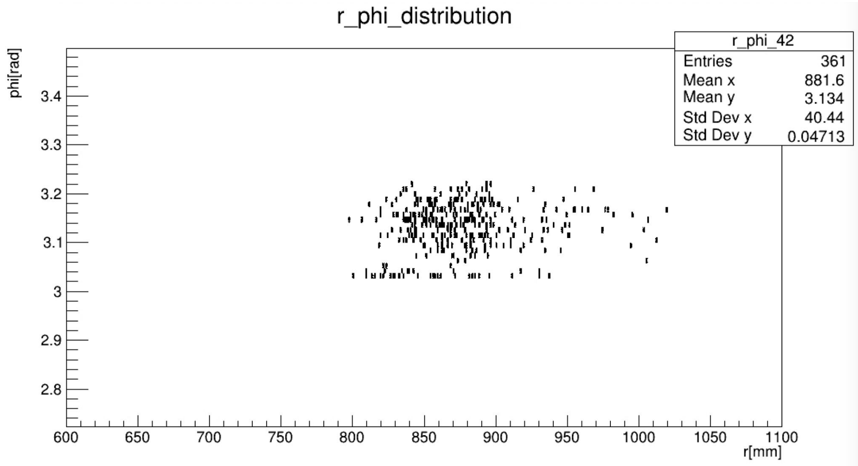
From looking at the r vs phi plots, holes 23 and 42 look a little messy for pass 5 data:

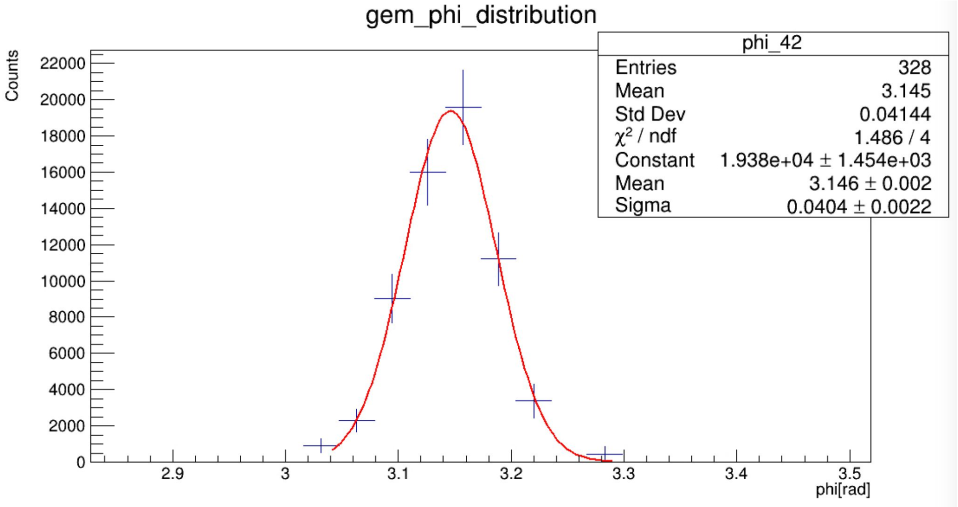






Individual distributions for hole 23, the center hole





Individual distributions for hole 42, the center hole

Conclusions

- We should be mindful of this when we end up fitting confidence ellipses.
- More statistics may help the ellipses exclude results from the other holes.
- Moller data may require later cuts applied to the CSV files, but I don't want to tighten the initial cuts so that we don't lose shifts from the magnetic field asymmetries
- This does NOT seem to be an issue for elasticC12 data (which makes sense)