Cameron Clarke

Integrating Detector Progress Report

Update 9-27-2017

MOLLER Detector Meeting

Progress:

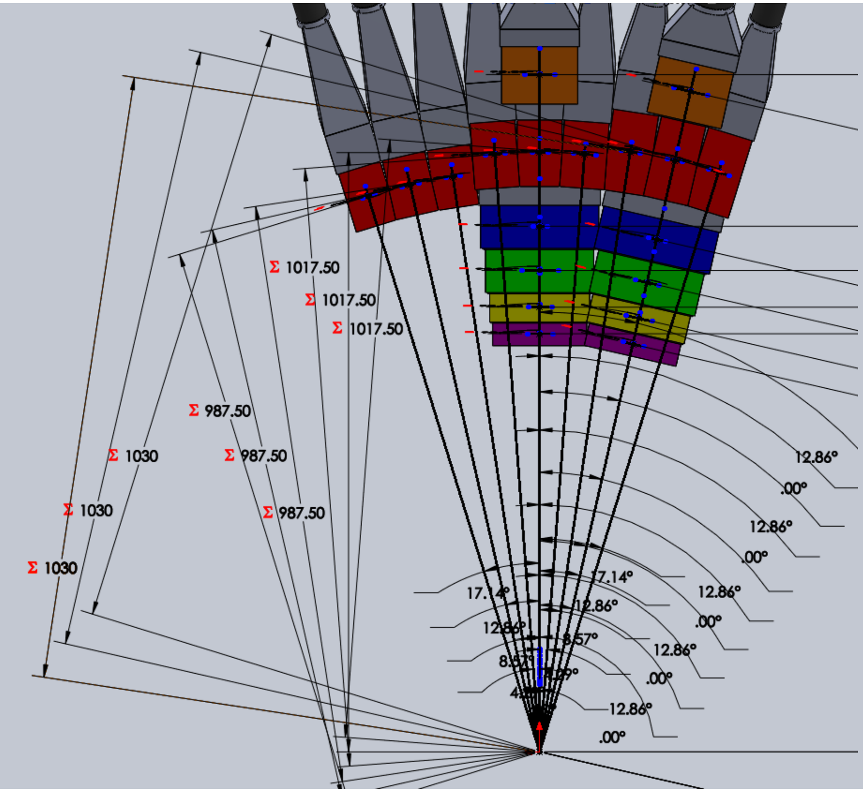
- Parametrized Detector Array
  - CAD Design
  - Geant4 GDML
  - Master parameter list

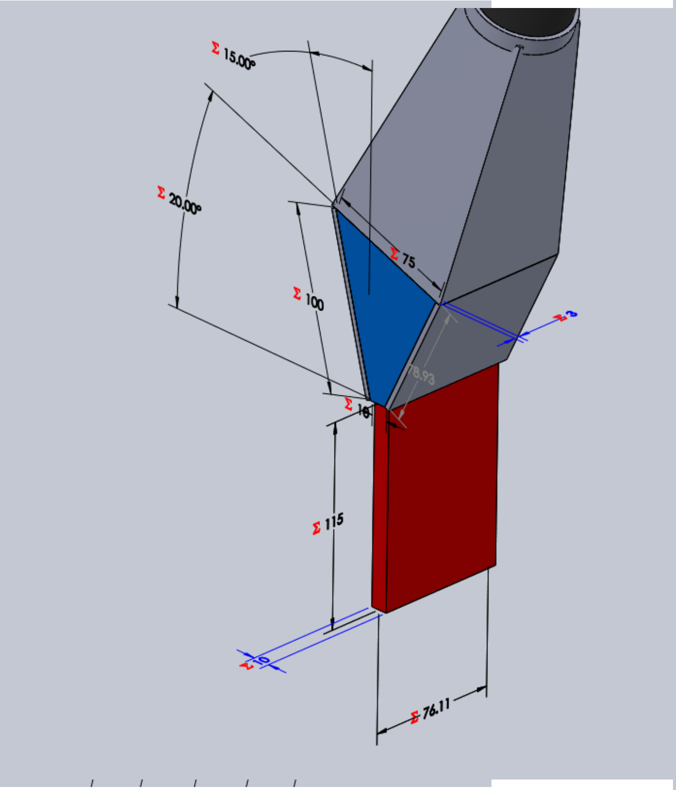
- Quick and dirty lightguide air-light backgrounds analysis for paper
  - Post-Mainz testbeam simulations (Ryan)
  - Applying Yuxiang’s updated asymmetry information
  - Preliminary light guide length scanning simulations
  - Back of the envelope determination of backgrounds in various rings
  - Next step – more precise simulations

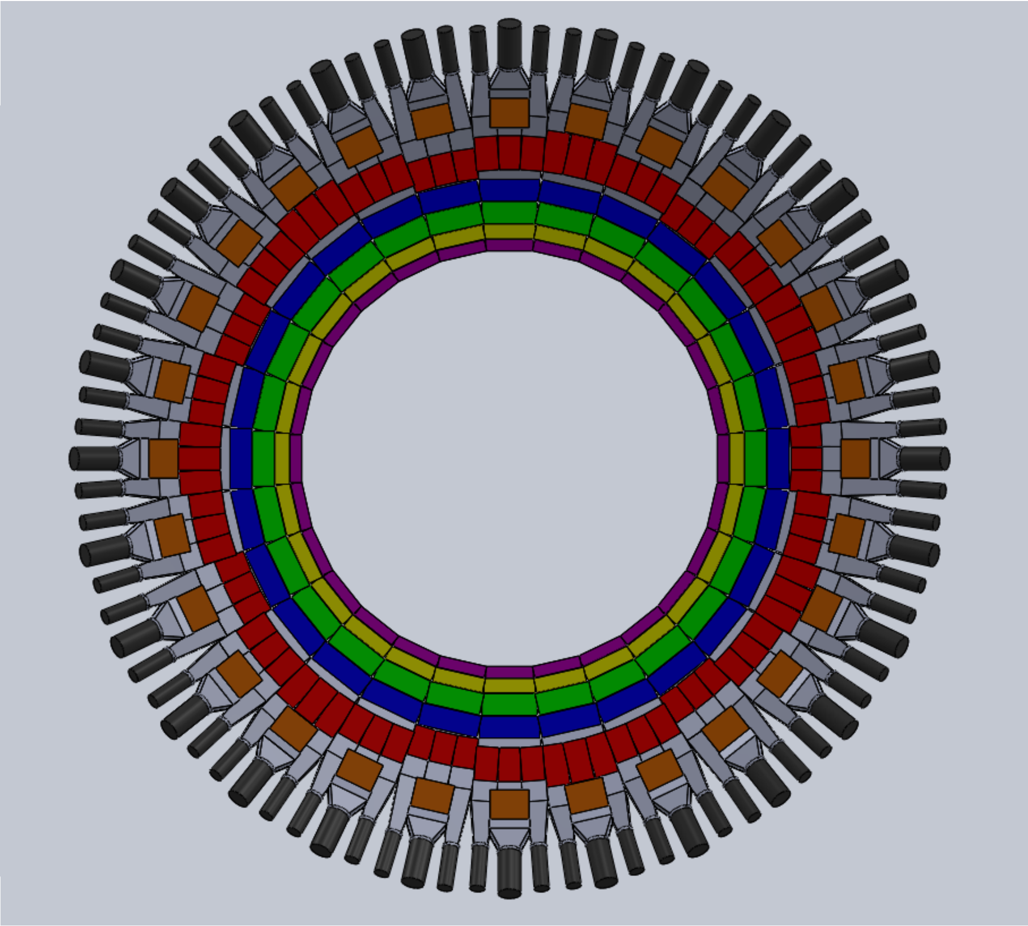
- Two Bounce Code for grounding the radiation shielding simulations in the reality of protecting the detector plane

Parametrized Detector Array

I have completed the SolidWorks CAD design and parametrized the dimensions for the MOLLER Detector Array:

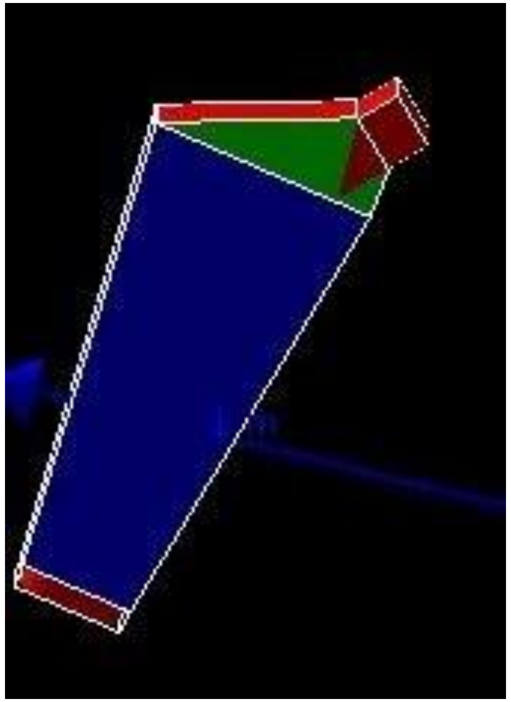


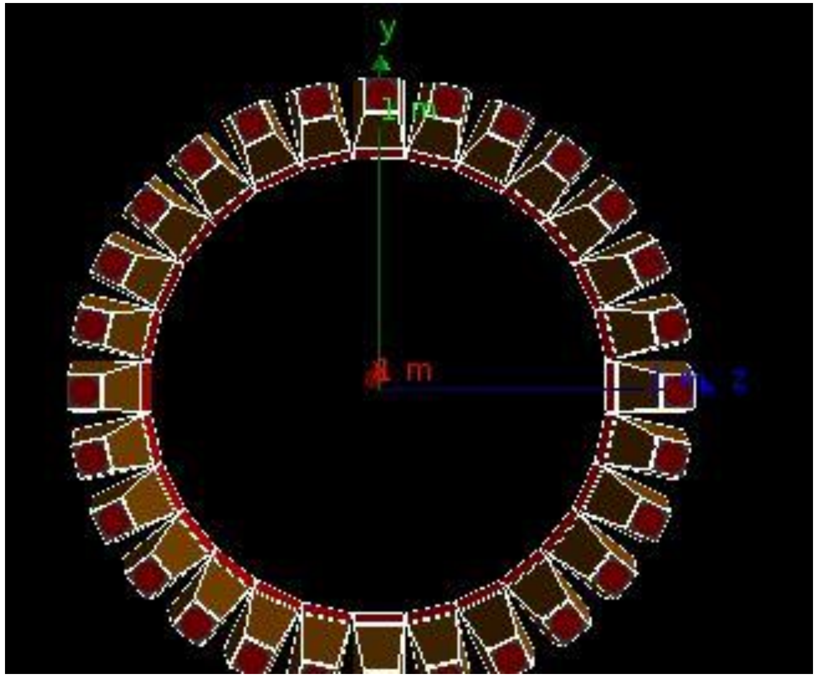




Parametrized Detector Array

Sakib has completed the Geant4 GDML and Perl script design and has also fully parametrized all dimensions for the MOLLER Detector Array:





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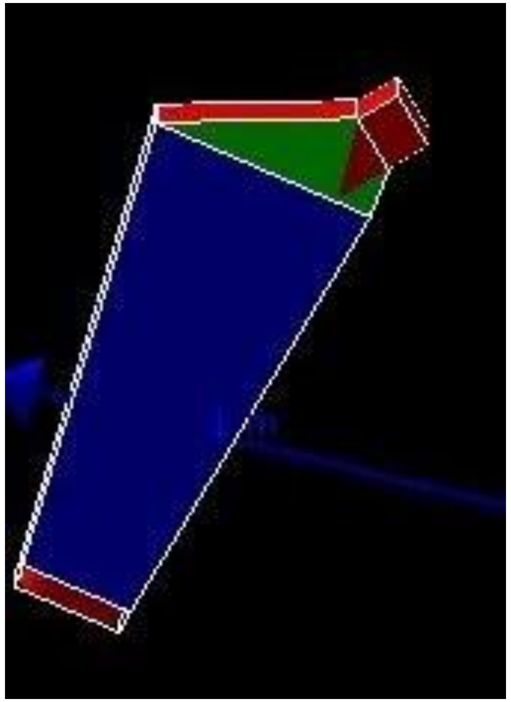
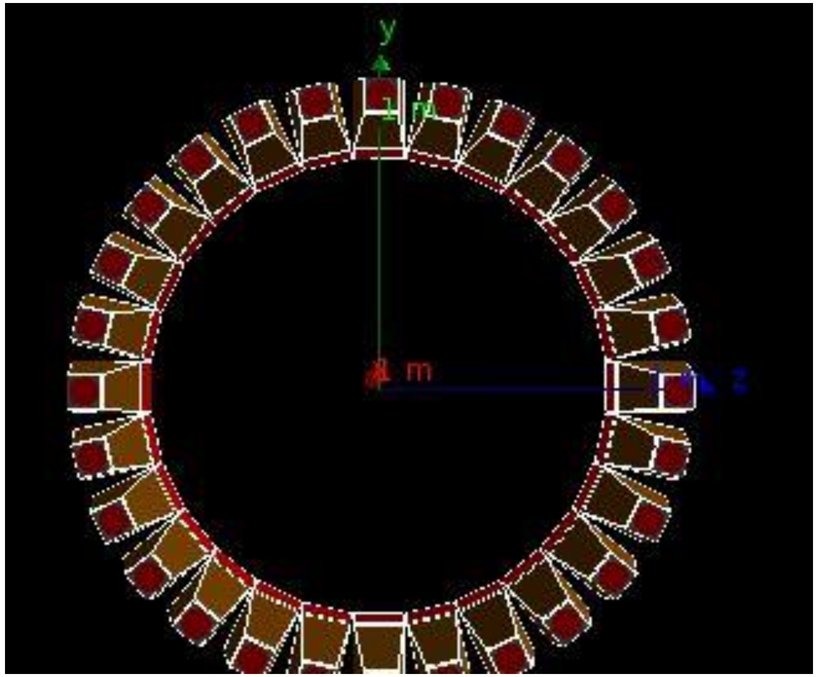




Sakib has also fully coded a Perl system for tying both together with one master equation list

We can now do tests of various geometries to make sure the two systems are exactly equal and then implement them fully into the CAD and Geant4 simulations

Quick and dirty lightguide air-light backgrounds analysis for paper

Post-Mainz testbeam simulations

- Mainz Beamtest
  - Scintillation and Cherenkov in different gases test with Seamus's tube detector:
    - We find that air as the medium is good enough without needing more CO2 to quench the scintillation (see upcoming paper).
  - Moller and Super-elastic light guide prototype geometry tests (Ryan and Brad):
    - Simulation results match Mainz data, except for some discrepancies with RMS over mean which is ongoing.
    - We will use 1.5 cm single cut quartz.
    - Geometries are good to go, with some ongoing investigations into blackening tweaks w.r.t. the Cherenkov backgrounds.

Quartz Simulations (Ryan)

- Simulations for Møller protoypes with light guides (both 1cm and 2cm thick single-cut quartz)

- 2cm single-cut data (Two mounts – vertical mount and horizontal mount)

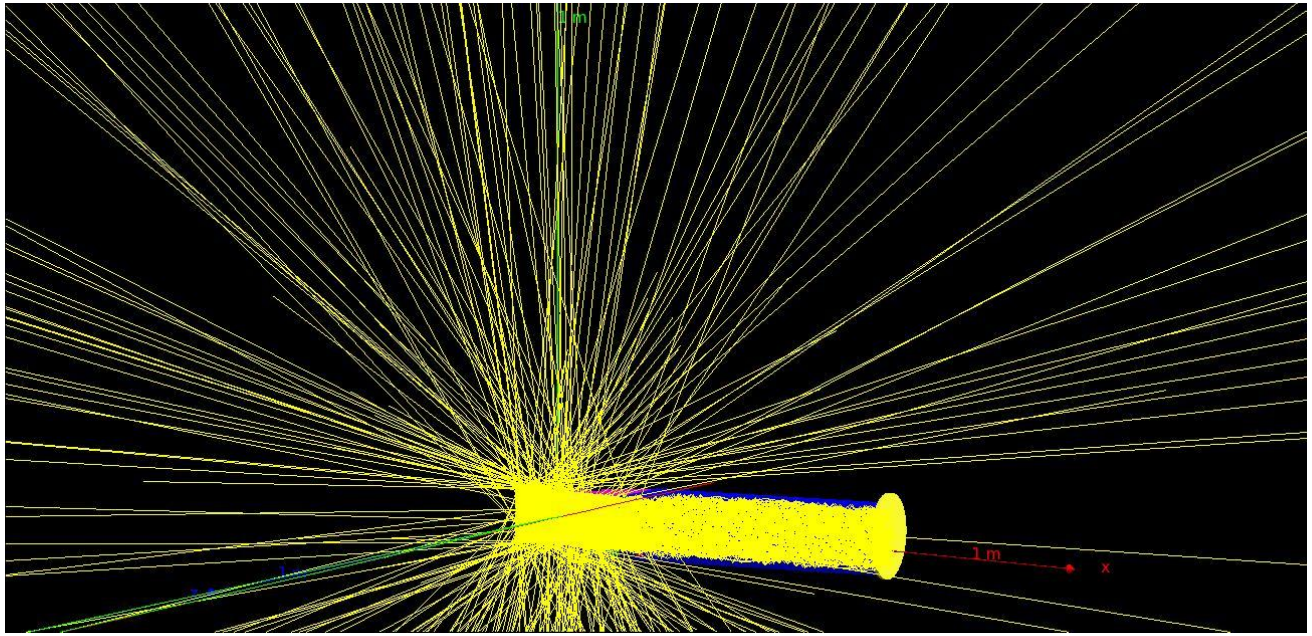
<u>Relevant Simulation Inputs</u>

1. 855 MeV beam

2. 0.975 quartz polish

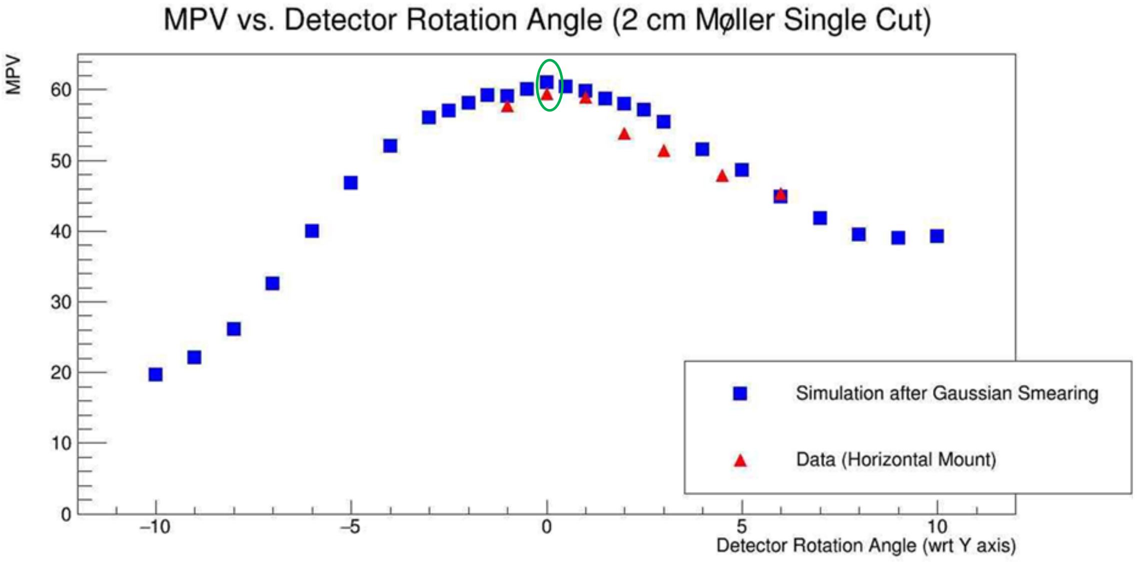
3. Mirror Reflectivity Table

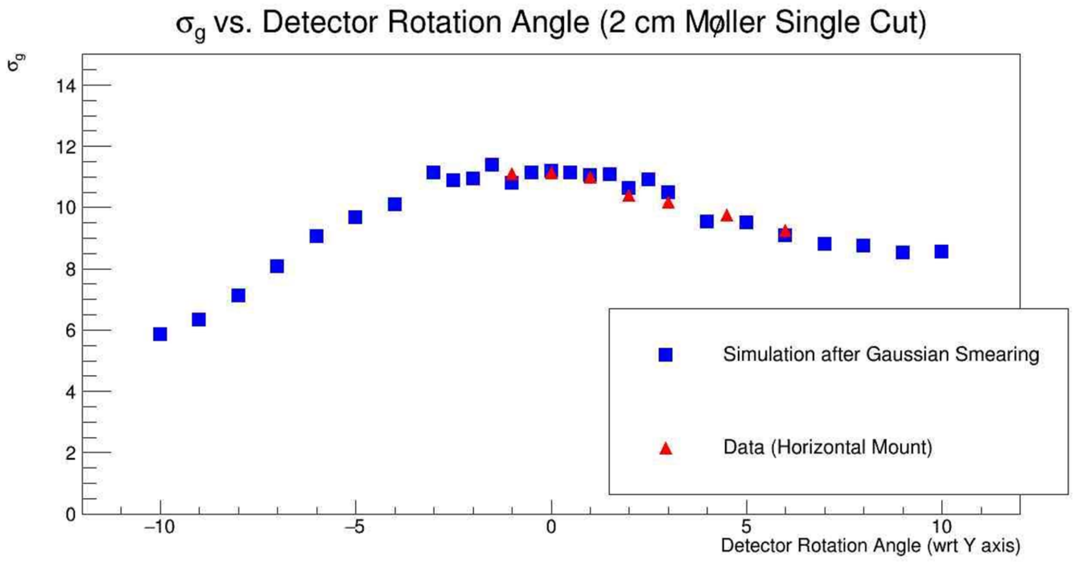
4. Quantum Efficiency Table (3” 9305QKB PMT)



Simulation for 2cm single-cut quartz (Horizontal Orientation)
Magenta – Detector parts, Blue – Light Guide, Yellow - photocathode

Simulation Results





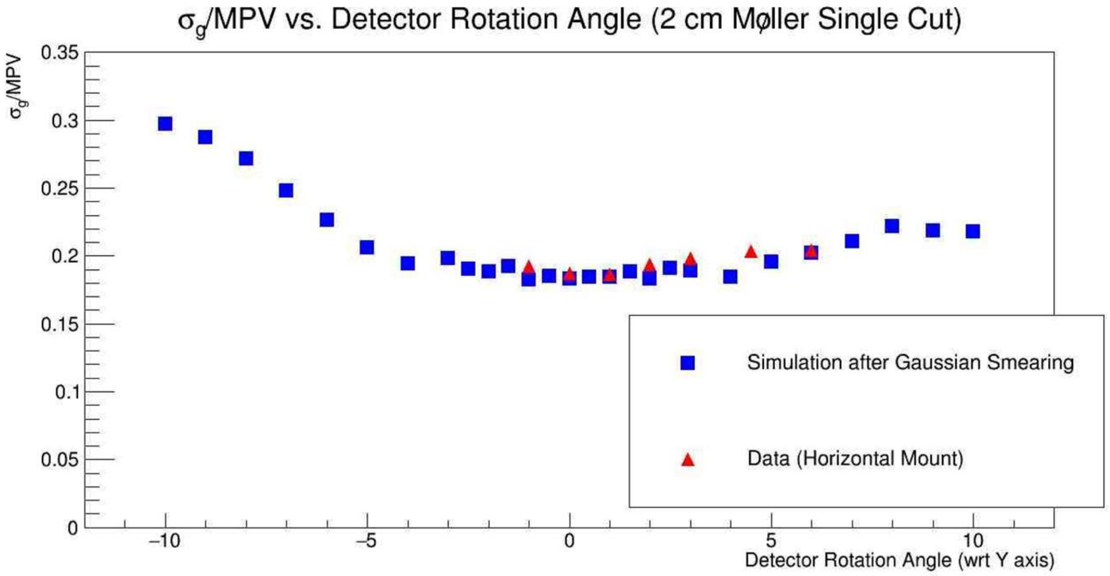
- Modeled the Gaussian PMT response with smear parameter σ_1 using data at normal beam incidence as a reference point. Fine tune that parameter to match various quantities (e.g Moller 2cm single-cut $\sigma_1 = 1.09$)

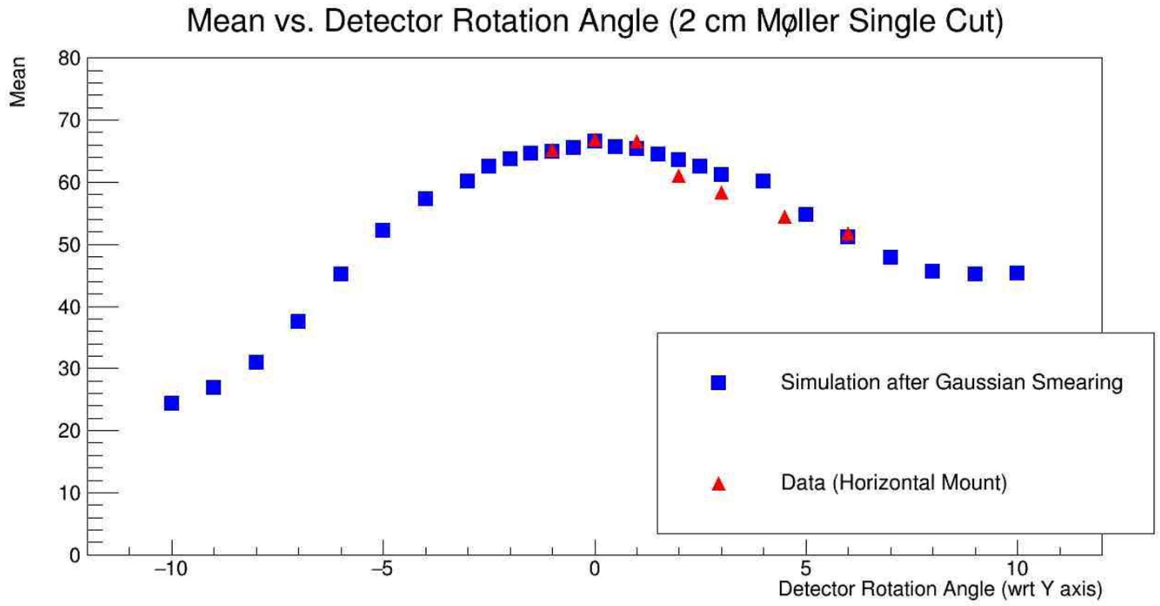
- Red data points have error on x-axis ~ $\pm$ 2°

- ADC conversion ~ 0.0855 PE/channel

Simulation Results

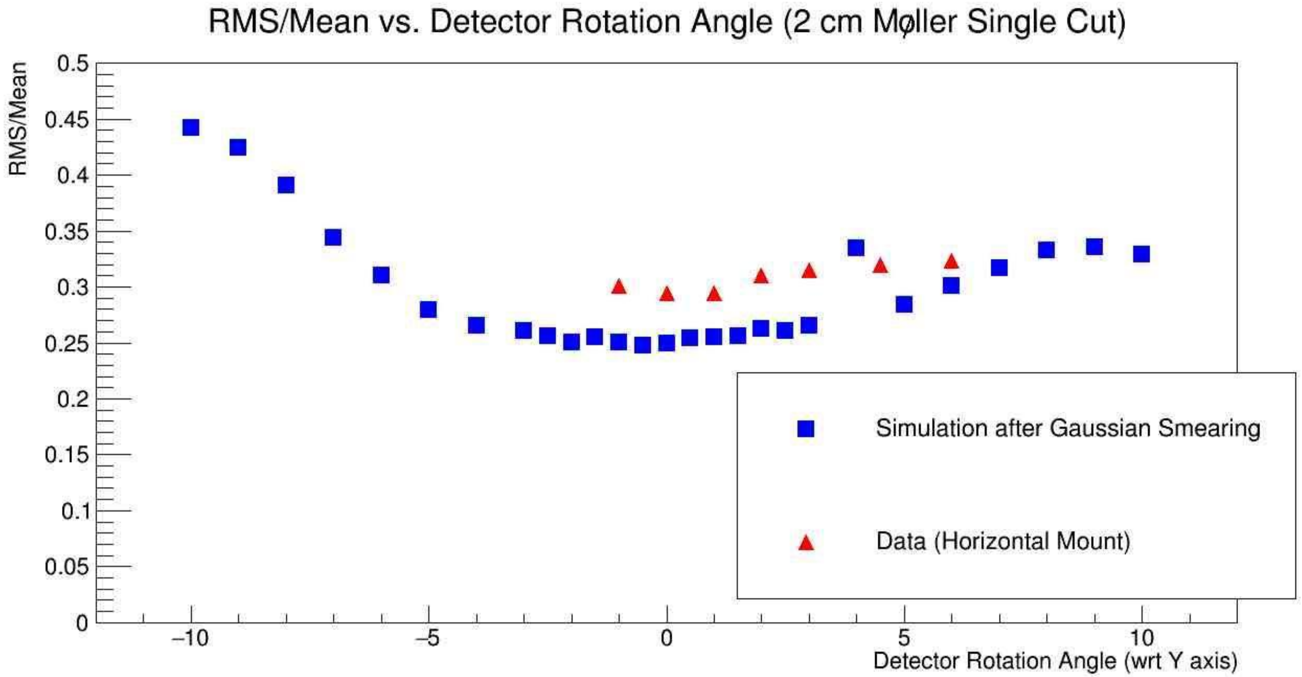
$\sigma_1 = 1.09$





- Pretty good agreement between simulation and Mainz data

Møller 2 cm Single –Cut (RMS/Mean)



Here is where the main issue lies, we see the simulation predicts a much lower RMS/Mean than the data
Needs further investigation (Looking at phi dependence to see if this has any significance on the tail, examining how changing the quartz polish influences the tail)

Quick and dirty lightguide air-light backgrounds analysis for paper

Applying Yuxiang’s updated asymmetry information

Using Yuxiang’s predicted asymmetries and uncertainties in different rings, we:

- Calculated an estimate of the total relative flux passing through each quartz block.

Flux is proportional to

$1/(\sigma/A)^2 * 1/A^2$

since we are looking at the uncertainty on an asymmetry signal

ring #	sector ID	$\frac{\sigma_A}{A}$ (%)	A_m (ppb)	Møller (%)	e-p elastic (%)	e-p inelastic (%)	e-Al elastic (%)	e-Al quasi-elastic (%)	e-Al inelastic (%)	pions (%)
1	0	9.92	-282.1	0.16	81.6	19.1	-1.06	0	0.23	0
1	1	2.55	-278.2	0	71.7	30.7	-3.29	0	0.87	0
1	2	5.04	-50.92	0	85.7	27.5	-14.6	0	1.34	0
2	0	2.30	-412.2	0	42.5	58.1	-2.50	0	1.77	0.10
2	1	1.18	-203.8	0	56.7	48.0	-6.57	0	1.79	0.06
2	2	1.88	-68.51	0	75.2	39.2	-16.3	0	1.87	0
3	0	3.54	-288.7	0.07	38.0	61.3	-3.55	0	1.21	2.94
3	1	1.83	-176.0	0.06	45.1	58.5	-6.39	0	1.41	1.28
3	2	2.94	-60.01	2.19	56.7	49.6	-10.5	0	1.29	0.75
4	0	6.72	-134.4	3.38	41.8	44.3	-5.22	0	0.76	14.9
4	1	3.83	-98.73	4.91	48.3	41.2	-8.02	0	0.82	12.7
4	2	4.40	-33.88	49.7	32.6	20.7	-7.24	0	0.52	3.60
5	0	4.74	-31.86	87.3	5.46	3.77	-0.82	0	0.08	4.24
5	1	2.57	-35.00	88.0	5.95	3.50	-1.17	0	0.08	3.60
5	2	2.29	-34.34	88.6	7.42	3.56	-1.87	0	0.10	2.17
6	0	21.9	-25.09	42.9	11.7	11.3	-2.43	0	0.30	36.2
6	1	11.2	-16.92	53.8	22.4	7.60	-5.97	0	0.27	21.9
6	2	9.91	-11.47	60.8	28.1	8.55	-8.73	0	0.32	10.9

Table 4: Total predicted asymmetry in each radial ring, A_m, and its statistical precision σ_A/A along with the fractional contributions to the measured asymmetries from each relevant process. “0” indicates that the fraction is less than 0.05%. The definitions of each ring in terms of radius and are given in Fig. 4. The three ϕ sectors are defines as follows: “2” corresponds to a 1/28th fraction of the full range of the azimuth that is centered on an open 1/7th sector of the acceptance collimator, while “0” corresponds to the closed sector of the same ϕ width. The “1” corresponds to the sector in between a “0” and a “2”.

Quick and dirty lightguide air-light backgrounds analysis for paper

Preliminary light guide length scanning simulations

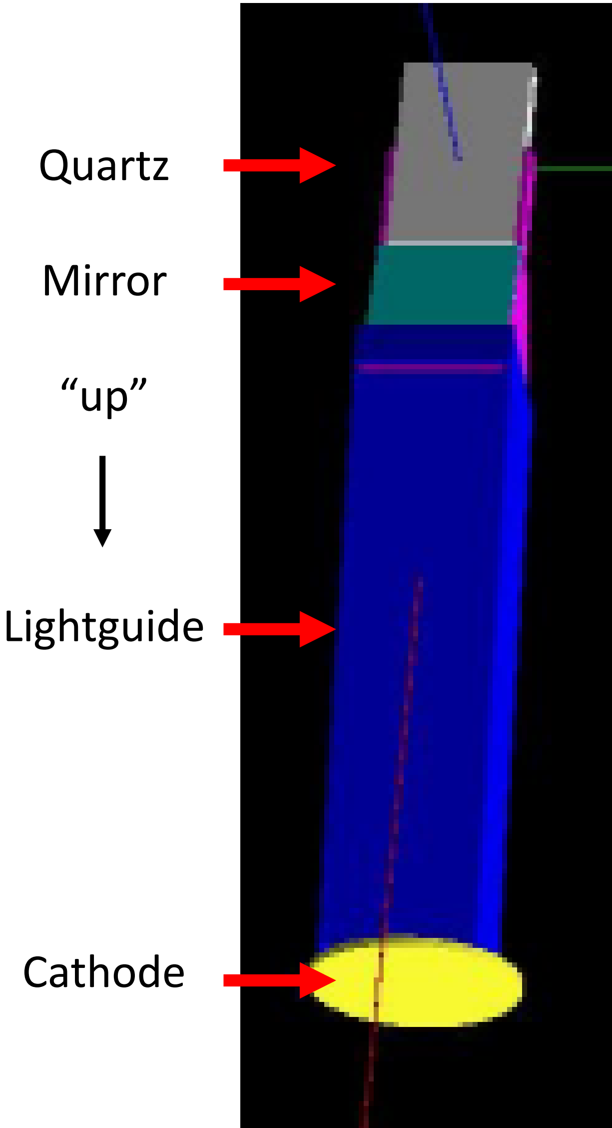
Using Yuxiang's predicted asymmetries and uncertainties in different rings, we:

- Calculated an estimate of the total relative flux passing through each quartz block.
- Performed position dependent scans using Brad's simulations of the Moller lightguide and reflector (3 degree incidence, 0.9 reflectivity, 100K Events).
- Made rough estimates of the mean P.E. at various positions based on these results.

14 simulation scan of Moller Lightguide design

% up the mirror (from bottom to top)	Mean P.E.
0	0.09825
25	0.18065
50	0.03541
75	0.03553
100	0.96725

% up the light guide (from bottom to top)	Mean P.E.
0	0.03553
12.5	0.04096
25	0.04587
37.5	0.04876
50	0.05292
62.5	0.0656
75	0.09692
87.5	0.09994
100	0.1279



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Back of the envelope determination of backgrounds in various rings

Using Yuxiang's predicted asymmetries and uncertainties in different rings, we:

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- Made rough estimates of the mean P.E. at various positions based on these results.
- Combined this with the information from Yuxiang to make predictions about relative P.E. count influence through different rings

Column-Lightguide's ring+sector (with geometrical P.E. counts factored in)
Divided by Row-Quartz's ring+sector

Signal Ring#	and Sector ID	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6
1	0	100.0	4.8	0.8	1.1	76.3	5.8
1	1	100.0	4.8	0.5	0.4	13.8	3.1
1	2	100.0	2.2	0.2	0.3	2.4	1.1
2	0		100.0	0.5	0.1	8.8	0.7
2	1		100.0	0.3	0.0	1.6	0.4
2	2		100.0	0.3	0.1	0.6	0.3
3	0			100.0	0.7	10.2	0.8
3	1			100.0	0.4	2.8	0.6
3	2			100.0	0.8	1.1	0.2
4	0				100.0	19.9	0.6
4	1				100.0	9.8	0.9
4	2				100.0	2.0	0.4
5	0					100.0	0.0
5	1					100.0	0.1
5	2					100.0	0.3
6	0						100.0
6	1						100.0
6	2						100.0

To get these percent P.E. signal results I take the flux through LG/through quartz * P.E.'s for that geometrical region/for quartz ~ 1/0.1*0.1/45 ~ 2%

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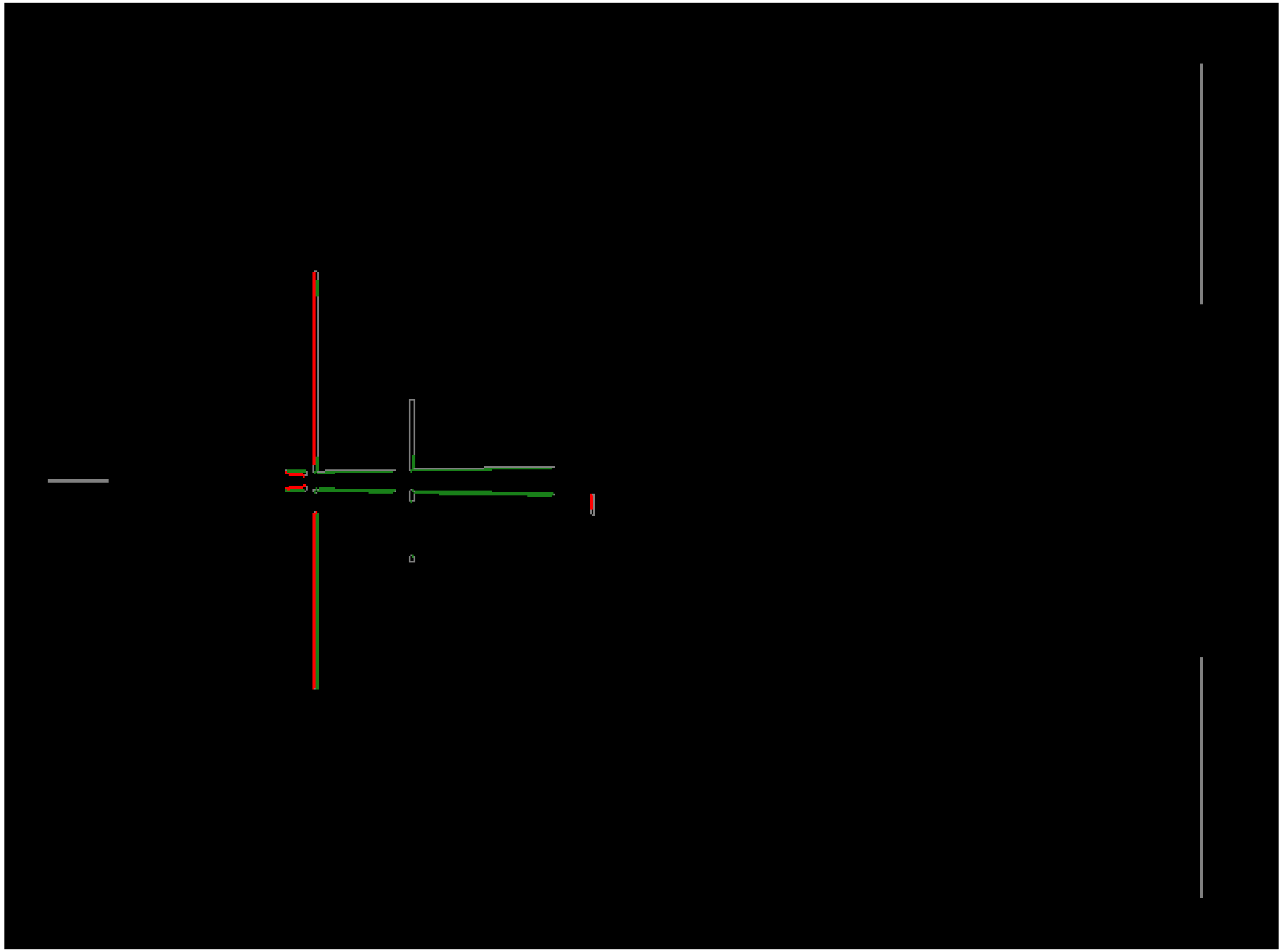
1	2	100.0	2.2	0.2	0.3	2.4	1.1
2	0		100.0	0.5	0.1	8.8	0.7
2	1		100.0	0.3	0.0	1.6	0.4
2	2		100.0	0.3	0.1	0.6	0.3
3	0			100.0	0.7	10.2	0.8
3	1			100.0	0.4	2.8	0.6
3	2			100.0	0.8	1.1	0.2
4	0				100.0	19.9	0.6
4	1				100.0	9.8	0.9
4	2				100.0	2.0	0.4
5	0					100.0	0.0
5	1					100.0	0.1
5	2					100.0	0.3
6	0						100.0
6	1						100.0
6	2						100.0

Next step: Making more precise simulations of electron fluxes through the light guides

An undergrad will parametrize the various fluxes as a generator for Qsim simulation of all light guide geometries

Two Bounce Code for grounding the radiation shielding simulations in the reality of protecting the detector plane

- I have resurrected Yuxiang and Seamus's two bounce code
- I am using it to test that the radiation shielding changes I am making are not badly affecting the detector plane
- I moved collimator 4 forward and extended its downstream beampipe
- It seems to work nicely
- Also, the beampipe may not need to be extended, just shifted forward enough



Summary

- An undergrad will continue to work on the MOLLER detector geometry simulations and measure and reduce (through blackening the interior) the expected scintillation and Cherenkov signal backgrounds.
- Ryan will continue to investigate the differences between some simulations and Mainz testbeam data.
- I will work with Sakib to implement the parametrized detector fully into the main CAD and into the main remoll simulation.
- I will continue to update the two bounce code along with my work in the radiation shielding simulations.