Background studies

Ciprian Gal UVa

Simulation status

- I rerun the simulation to contain 1e7 events for all processes
  - I used the code base that Yuxiang provided in tar ball (there are a couple of differences that were not ported to the main repo)

Code differences

GenpElastic YZ:

```
    double thisZ;

    thisZ = vert->GetMaterial()->GetZ();

//---Yuxiang
//     thisZ=13*13.0;
    evt->SetEffCrossSection(sigma*V*thisZ*value);
```

GenpElastic repo:

```
    double thisZ;

    thisZ = vert->GetMaterial()->GetZ();

    evt->SetEffCrossSection(sigma*V*thisZ*thisZ*value);
```

GenAl quasiElastic YZ:

```
///~~~ Aymmetry calculation //
const G4double gf=1.16637e-5;//fermi coupling [GeV^-2]
const G4double qwp=0.0713;
const G4double qwn=-0.988;
//---Modified by Yuxiang Zhao,
//---only using QWP as weak charge
asym= -gf/(4.*pi*fine_structure_const*sqrt(2.)) * Q2/GeV/GeV * (qwp);
```

GenAl quasiElastic repo:

```
///~~~ Aymmetry calculation //FIXME -- this is just a copy of the elastic for now
const G4double gf=1.16637e-5;//fermi coupling [GeV^-2]
const G4double qwp=0.0713;
const G4double qwn=-0.988;

asym= -gf/(4.*pi*fine_structure_const*sqrt(2.)) * Q2/GeV/GeV * (qwp+qwn*(A-Z)/Z);
```

- The rest of the code seems to be functionally identical

Simulation results (YZ code)

		Moller			e-p Elastic			e-p Inelastic			e-Al Elastic			e-Al Inelastic			e-Al Quasielastic			pion				
R	S	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A[ppb]	f*A[ppb]	f*A [% of Am]	A measured [ppb]	dA [ppb]
1	0	-34.38	-0.02	0.01%	-209.58	-204.86	83.92%	-2096.34	-41.41	16.96%	2711.35	6.24	-2.56%	-195.32	0.00	0.00%	-2460.93	0.00	0.00%	0.00	0.00	0.00%	-244.12	25.12
1	1	-5.31	-0.02	0.01%	-221.96	-210.90	71.48%	-2048.48	-87.44	29.64%	2332.49	7.79	-2.64%	-175.98	0.00	0.00%	-2222.63	0.00	0.00%	0.00	0.00	0.00%	-295.04	7.31
1	2	-12.16	0.00	0.01%	-46.52	-45.46	85.11%	-1458.50	-13.82	25.87%	512.02	6.64	-12.44%	-72.91	0.00	0.00%	-935.37	0.00	0.00%	0.00	0.00	0.00%	-53.41	2.58
2	0	-11.90	-0.04	0.01%	-206.04	-178.48	40.86%	-1990.40	-255.19	58.42%	2418.25	4.33	-0.99%	-216.92	0.00	0.00%	-2551.38	0.00	0.00%	0.00	0.00	0.00%	-436.85	9.63
2	1	-10.17	-0.01	0.00%	-131.13	-120.82	53.99%	-1550.86	-108.41	48.45%	1406.43	10.86	-4.85%	-151.11	0.00	0.00%	-1914.14	0.00	0.00%	0.00	0.00	0.00%	-223.76	2.55
2	2	-9.79	-0.01	0.01%	-54.98	-52.59	72.99%	-900.45	-27.54	38.22%	801.57	9.71	-13.48%	-86.99	0.00	0.00%	-1019.06	0.00	0.00%	0.00	0.00	0.00%	-72.05	1.31
3	0	-23.36	-0.21	0.07%	-135.14	-118.30	41.29%	-1442.60	-166.78	58.21%	0.00	0.00	0.00%	0.00	0.00	0.00%	-1993.51	0.00	0.00%	0.00	0.00	0.00%	-286.54	10.25
3	1	-17.78	-0.12	0.06%	-90.86	-80.82	41.78%	-1072.12	-110.90	57.33%	1729.18	0.07	-0.03%	-129.57	0.00	0.00%	-1416.21	0.00	0.00%	0.00	0.00	0.00%	-193.45	3.47
3	2	-20.43	-1.37	2.04%	-38.70	-34.24	50.88%	-651.17	-31.33	46.56%	0.00	0.00	0.00%	0.00	0.00	0.00%	-873.84	0.00	0.00%	0.00	0.00	0.00%	-67.30	1.78
4	0	-37.94	-5.32	4.01%	-76.07	-60.48	45.55%	-1035.39	-66.94	50.42%	0.00	0.00	0.00%	0.00	0.00	0.00%	-1245.97	0.00	0.00%	0.00	0.00	0.00%	-132.78	9.59
4	1	-35.23	-5.09	5.21%	-61.74	-49.48	50.68%	-794.06	-42.97	44.01%	640.56	0.00	0.00%	0.00	0.00	0.00%	-864.98	0.00	0.00%	0.00	0.00	0.00%	-97.64	3.86
4	2	-28.95	-16.89	48.15%	-27.27	-10.99	31.34%	-524.31	-7.17	20.45%	0.00	0.00	0.00%	0.00	0.00	0.00%	-568.15	0.00	0.00%	0.00	0.00	0.00%	-35.07	1.49
5	0	-30.77	-28.57	90.40%	-25.17	-1.75	5.55%	-784.06	-1.28	4.06%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	-31.61	0.91
5	1	-34.03	-30.95	89.80%	-25.01	-2.20	6.40%	-578.19	-1.31	3.80%	143.02	0.00	0.00%	0.00	0.00	0.00%	-536.20	0.00	0.00%	0.00	0.00	0.00%	-34.47	0.52
5	2	-34.51	-29.25	88.58%	-17.81	-2.66	8.06%	-381.01	-1.11	3.36%	245.90	0.00	0.00%	0.00	0.00	0.00%	-365.45	0.00	0.00%	0.00	0.00	0.00%	-33.02	0.46
6	0	-16.82	-9.22	65.86%	-6.90	-3.10	22.15%	-651.35	-1.68	11.99%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	-14.00	5.09
6	1	-17.27	-9.19	62.95%	-8.34	-3.87	26.52%	-435.47	-1.54	10.53%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	-14.60	1.91
6	2	-15.72	-6.95	62.01%	-5.81	-3.22	28.75%	-308.78	-1.04	9.24%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	0.00	0.00	0.00%	-11.21	1.13

- This is the result of simply calculating a sum of the individual asymmetries in each ring/sector weighted by the relative rate

- Statistical uncertainty calculated using the total rate in each ring/sector, beam polarization of 80%, 235+95+14 days and 60 uA of current (not sure what the 24 is for)

```
127        double sigma_ee=sqrt(F(0,0))/0.8/sqrt((235+95+14)*24.0*60*60);
```

https://github.com/cipriangal/remoll/blob/master/rootScripts/mollerBkgStudy/yield_error_matrix_window_4.C#L127

Simulation results (YZ results)

ring #	sector ID	Møller (%)	e-p elastic (%)	e-p inelastic (%)	e-Al elastic (%)	e-Al quasi-elastic (%)	e-Al inelastic (%)	pions (%)
1	0	0.16	81.6	19.1	-1.06	0	0.23	0
1	1	0	71.7	30.7	-3.29	0	0.87	0
1	2	0	85.7	27.5	-14.6	0	1.34	0
2	0	0	42.5	58.1	-2.50	0	1.77	0.10
2	1	0	56.7	48.0	-6.57	0	1.79	0.06
2	2	0	75.2	39.2	-16.3	0	1.87	0
3	0	0.07	38.0	61.3	-3.55	0	1.21	2.94
3	1	0.06	45.1	58.5	-6.39	0	1.41	1.28
3	2	2.19	56.7	49.6	-10.5	0	1.29	0.75
4	0	3.38	41.8	44.3	-5.22	0	0.76	14.9
4	1	4.91	48.3	41.2	-8.02	0	0.82	12.7
4	2	49.7	32.6	20.7	-7.24	0	0.52	3.60
5	0	87.3	5.46	3.77	-0.82	0	0.08	4.24
5	1	88.0	5.95	3.50	-1.17	0	0.08	3.60
5	2	88.6	7.42	3.56	-1.87	0	0.10	2.17
6	0	42.9	11.7	11.3	-2.43	0	0.30	36.2
6	1	53.8	22.4	7.60	-5.97	0	0.27	21.9
6	2	60.8	28.1	8.55	-8.73	0	0.32	10.9

		Moller	e-p Elastic	e-p Inelastic	e-Al Elastic	e-Al Inelastic	-Al Quasielasti	pion		
R	S	f*A [% of Am]	f*A [% of Am]	f*A [% of Am]	f*A [% of Am]	f*A [% of Am]	f*A [% of Am]	f*A [% of Am]	A measured [ppb]	dA [ppb]
1	0	0.01%	83.92%	16.96%	-2.56%	0.00%	0.00%	0.00%	-244.12	25.12
1	1	0.01%	71.48%	29.64%	-2.64%	0.00%	0.00%	0.00%	-295.04	7.31
1	2	0.01%	85.11%	25.87%	-12.44%	0.00%	0.00%	0.00%	-53.41	2.58
2	0	0.01%	40.86%	58.42%	-0.99%	0.00%	0.00%	0.00%	-436.85	9.63
2	1	0.00%	53.99%	48.45%	-4.85%	0.00%	0.00%	0.00%	-223.76	2.55
2	2	0.01%	72.99%	38.22%	-13.48%	0.00%	0.00%	0.00%	-72.05	1.31
3	0	0.07%	41.29%	58.21%	0.00%	0.00%	0.00%	0.00%	-286.54	10.25
3	1	0.06%	41.78%	57.33%	-0.03%	0.00%	0.00%	0.00%	-193.45	3.47
3	2	2.04%	50.88%	46.56%	0.00%	0.00%	0.00%	0.00%	-67.30	1.78
4	0	4.01%	45.55%	50.42%	0.00%	0.00%	0.00%	0.00%	-132.78	9.59
4	1	5.21%	50.68%	44.01%	0.00%	0.00%	0.00%	0.00%	-97.64	3.86
4	2	48.15%	31.34%	20.45%	0.00%	0.00%	0.00%	0.00%	-35.07	1.49
5	0	90.40%	5.55%	4.06%	0.00%	0.00%	0.00%	0.00%	-31.61	0.91
5	1	89.80%	6.40%	3.80%	0.00%	0.00%	0.00%	0.00%	-34.47	0.52
5	2	88.58%	8.06%	3.36%	0.00%	0.00%	0.00%	0.00%	-33.02	0.46
6	0	65.86%	22.15%	11.99%	0.00%	0.00%	0.00%	0.00%	-14.00	5.09
6	1	62.95%	26.52%	10.53%	0.00%	0.00%	0.00%	0.00%	-14.60	1.91
6	2	62.01%	28.75%	9.24%	0.00%	0.00%	0.00%	0.00%	-11.21	1.13

- For the most part the results I get with Yuxiang's code are consistent with the table in the Moller background write up

Simulation results (YZ code)

Am YZ [ppb]	sigma A	R	S	Am CG[ppb]	sigma A	(A_CG-A_YZ)/sqrt(dA_CG^2+dA_YZ^2)
-282.10	27.98	1	0	-244.12	25.12	1.0
-278.20	7.09	1	1	-295.04	7.31	-1.7
-50.92	2.57	1	2	-53.41	2.58	-0.7
-411.90	9.47	2	0	-436.85	9.63	-1.8
-203.70	2.40	2	1	-223.76	2.55	-5.7
-68.49	1.29	2	2	-72.05	1.31	-1.9
-281.70	9.97	3	0	-286.54	10.25	-0.3
-174.00	3.18	3	1	-193.45	3.47	-4.1
-59.58	1.75	3	2	-67.30	1.78	-3.1
-115.80	7.78	4	0	-132.78	9.59	-1.4
-86.81	3.32	4	1	-97.64	3.86	-2.1
-32.68	1.44	4	2	-35.07	1.49	-1.2
-30.54	1.45	5	0	-31.61	0.91	-0.6
-33.76	0.87	5	1	-34.47	0.52	-0.7
-33.61	0.77	5	2	-33.02	0.46	0.7
-16.10	3.53	6	0	-14.00	5.09	0.3
-13.24	1.48	6	1	-14.60	1.91	-0.6
-10.22	1.01	6	2	-11.21	1.13	-0.6

- Most my measured asymmetries are within 1 sigma of the values reported by Yuxiang
    - there are 3 places where we get >3 sigma discrepancies (not sure what could cause these differences)

Plan moving forward

- Yuxiang also provided the macro the used to do the matrix error calculation for including the eAl elastic process for the windows
  - I could extend it to use all processes if needed (the error matrix will have to vary in dimension from detector to detector due to low rates for some processes)
- The analysis is done using 18 detectors (6 rings each with 3 sectors), do we plan to extend this to 24 (5 rings with 3 sectors each + ring 5 with 9 sectors) ?

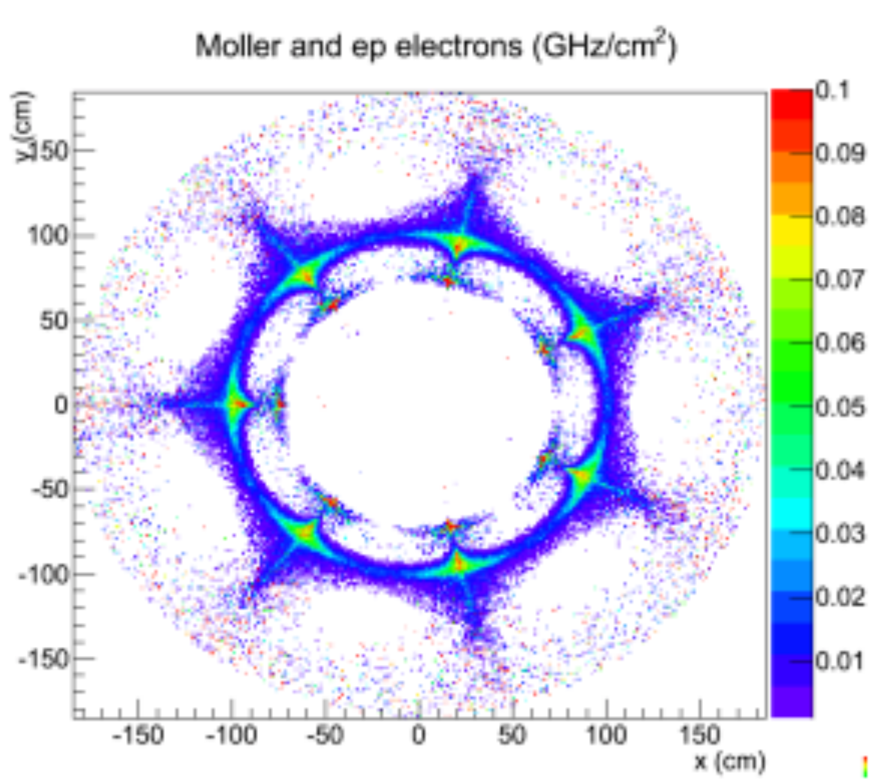

Figure 5: *Simulated, cross-section weighted, Møller and ep electron rates.*

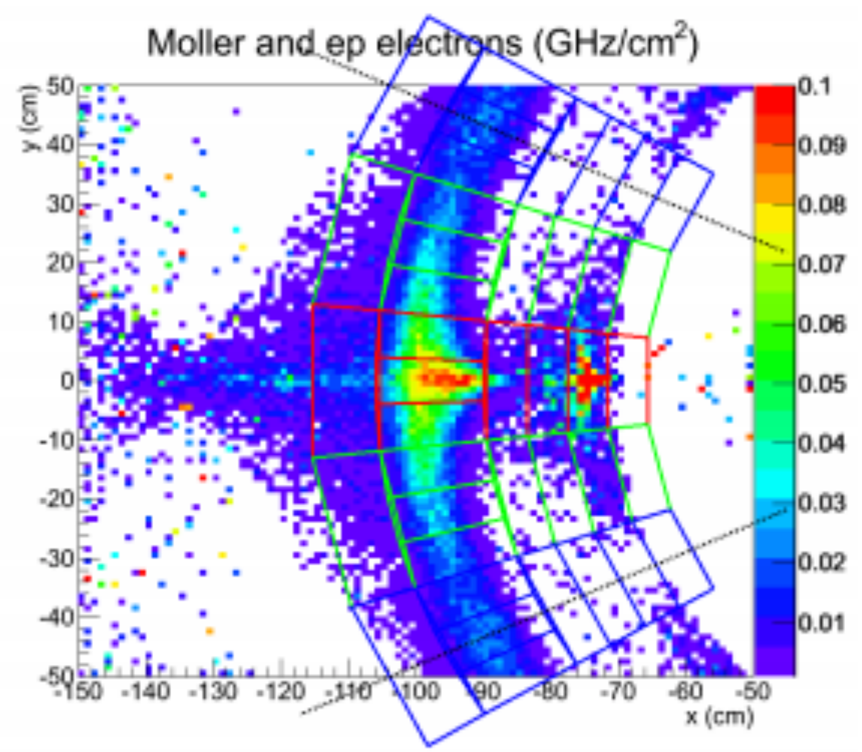

Figure 6: *Superimposed azimuthal and radial bins (detector locations) in one toriodal sector (indicated by the dotted black line).*