A_n Analysis Update

Feb 18, 2021

Dustin McNulty

(Idaho State University)

Ryan, Weibin, Devi, Caryn, Bob, Robert R., Paul K., Ciprian and Collaboration

Outline

- False asymmetries and new crex respin1
- Dilution factors and asymmetry correction
- A_n extraction; polarization and $\langle \cos\phi \rangle$
- Errors
- Q^2 changes
- Summary

False Asymmetries

PREX-2:

Analysis from Ryan following respin-2; posted in haplog 4160 (July 2020); Final -- no need to redo

	A_{raw}	dA_{raw}	A_{reg}	dA_{reg}	A_{dit}	dA_{dit}	Reg Diff	Dit Diff	$dFalse_{reg}$	$dFalse_{dit}$
C12	5267.752	740.798	5464.458	329.616	5493.883	330.014	191.706	226.131	49.177	56.532
Pb208	-201.844	666.141	22.688	125.958	24.461	127.647	224.532	226.305	56.133	57.576
Ca40	4439.244	1218.993	5276.284	288.271	5294.703	289.734	837.04	855.459	209.26	213.865

CREX:

Analysis from Weibin; posted in haplog 4144 (June 2020 – prompt output)

Target	Raw (ppb)	Regression (ppb)			Dithering (ppb)		
	A	A	$\lvert\Delta A\rvert$	A_{false}	A	$\lvert\Delta A\rvert$	A_{false}
C	-7813 ± 1090	-8528 ± 920.6	715	178.75	-8430 ± 921.5	617	154.25
Ca40	-8711 ± 1265	-8757 ± 975.2	46	11.5	-8700 ± 977	11	2.75
Ca48	-7860 ± 1142	-8283 ± 889.5	423	105.75	-8220 ± 891.6	360	90
Pb	-2955 ± 1882	-3253 ± 1737	298	74.5	-3317 ± 1739	352	88

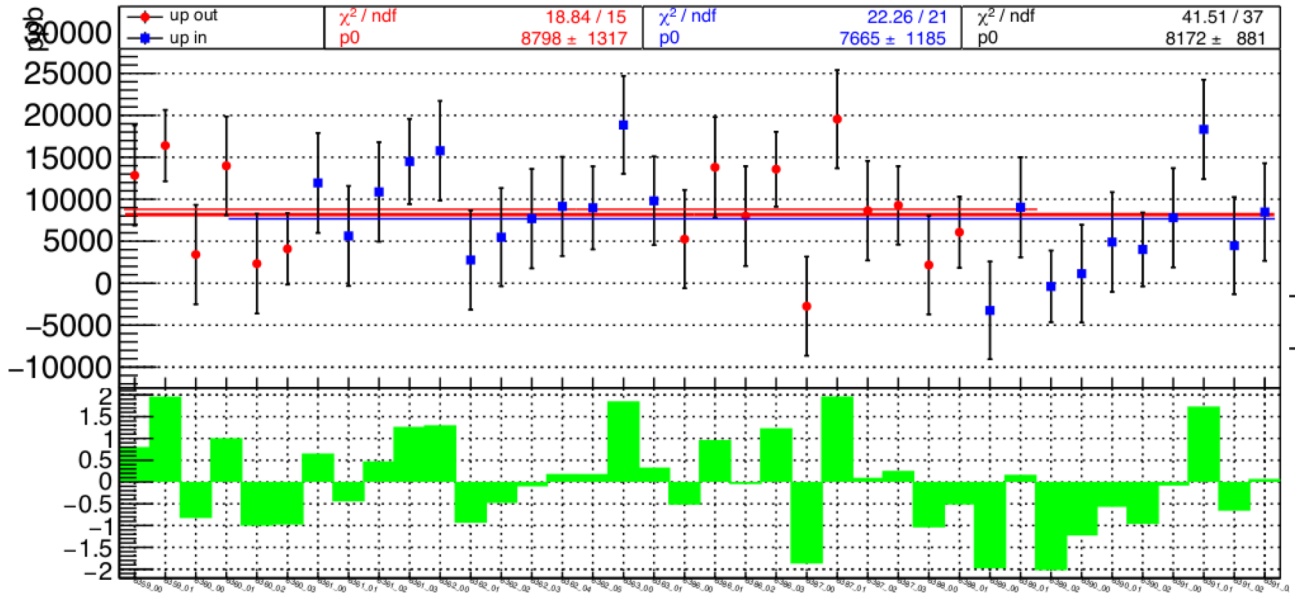
0.25*ΔA

(Feb 2021 – respin1 output haplog 4464)

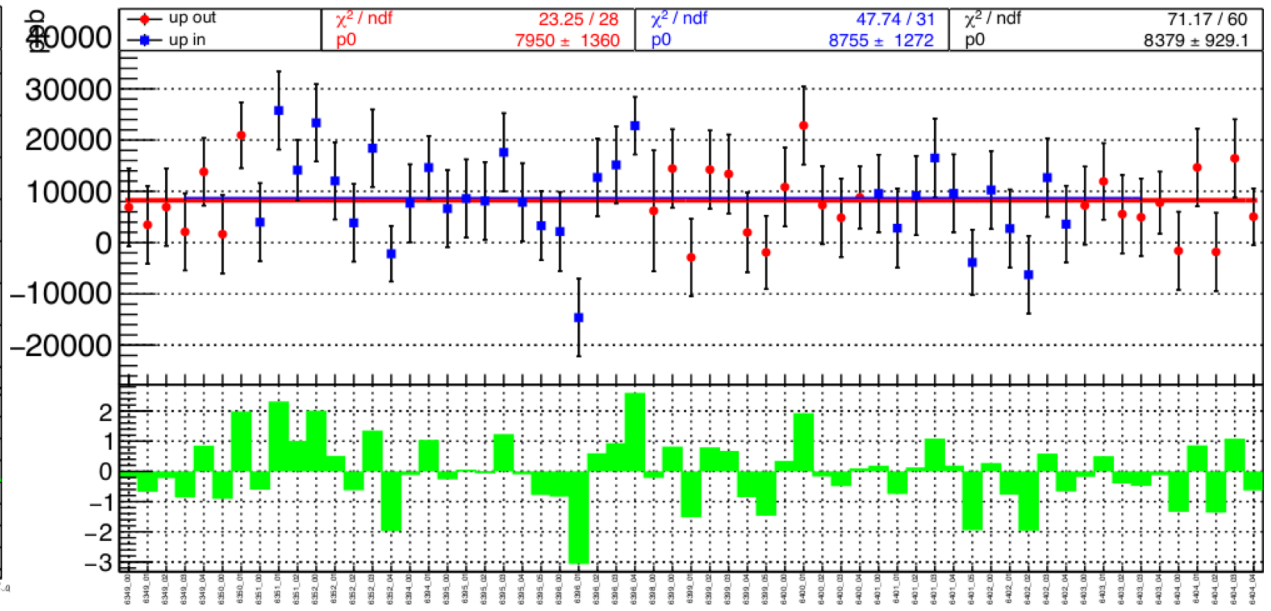
										$A_{false,\ dit}$
Carbon-12	-7628	1042	-8230	880.1	602	151	-8172	881.0	544	136
Ca40	-8350	1203	-8372	927.7	22	5.73	-8379	929	29	7.25
Ca48	-7802	1079	-7978	840.8	176	44.0	-7925	842	123	30.8
Pb208	-2446	1763	-2770	1628	324	81.1	-2820	1630	374	93.5

Respin1 CREX Asymmetries

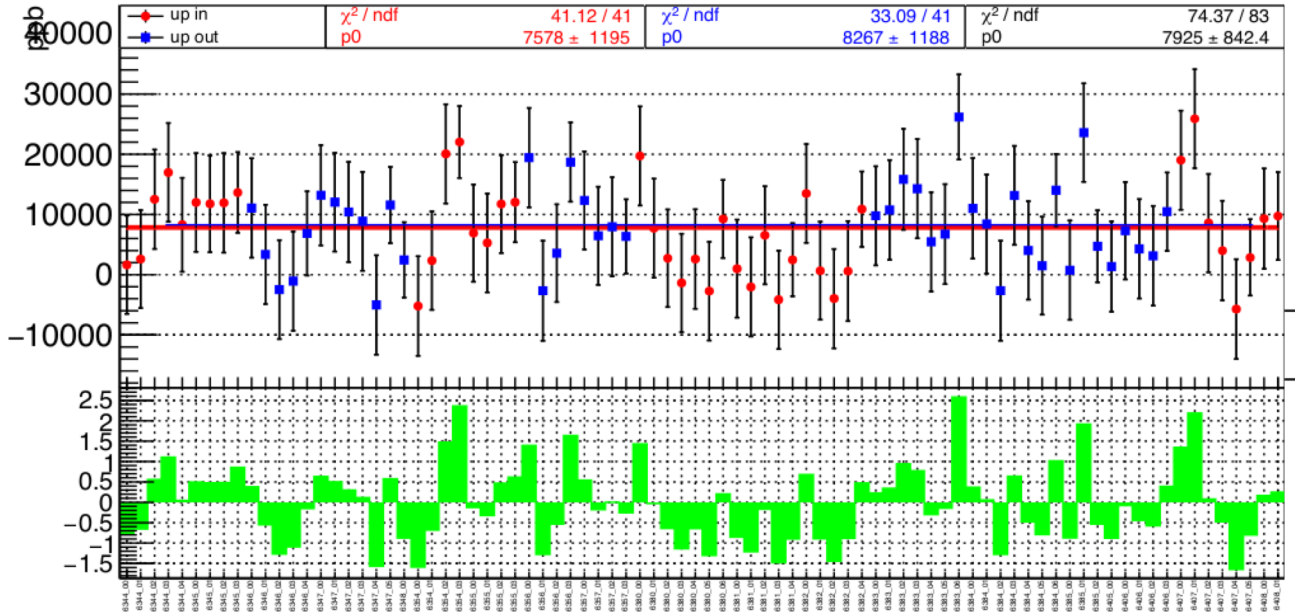
Carbon



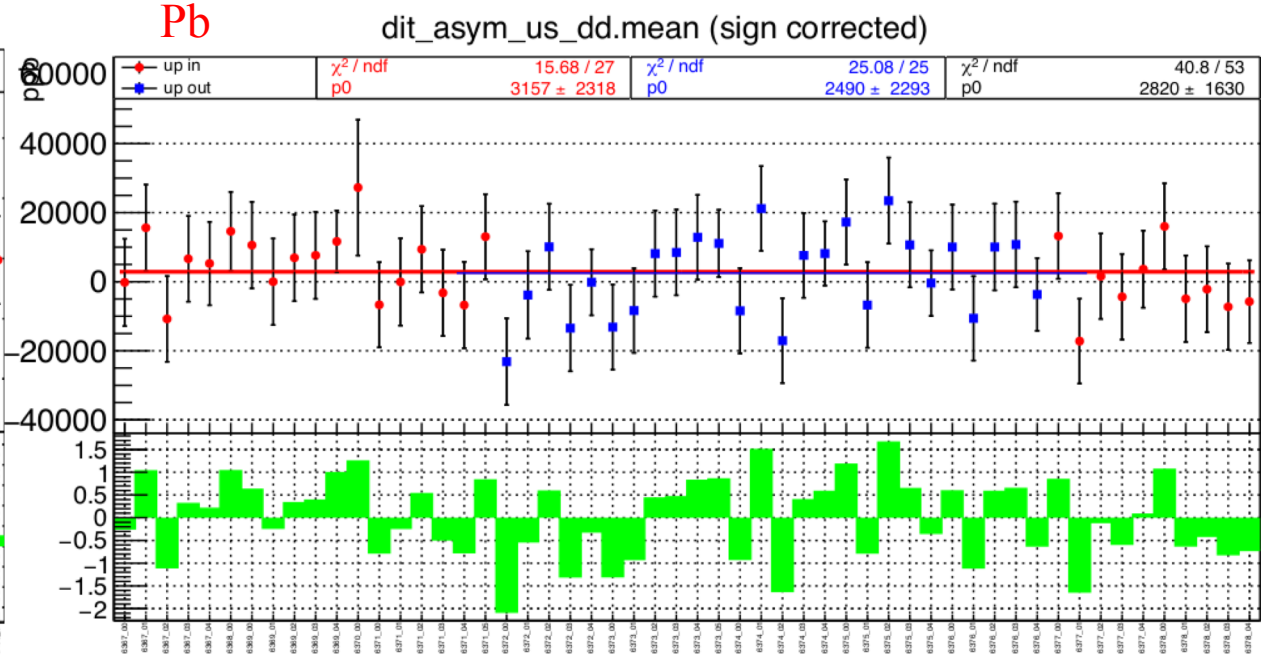
Ca-40



Ca-48



Pb



Dilution Factors and Asymmetry Correction

Pb data:

- Original (summer) analysis used the following formula for the carbon dilution correction:

$$A^{Pb}{}_{corr} = A^{dit}{}_{meas}(1 + f_{C,r}) - f_{C,r} A_C$$

Where $f_{C,r} = \frac{\text{rate\_C}}{\text{rate\_Pb}} = 0.0765 \pm 20\%$ for prex-2 and $0.89 \pm 20\%$ for crex (haplog 4129)

--these values came from averages of analyses using calculated rates and rates from real data widths

--new values calculated based on Weibin's prex-2 sim and FF^2/Q^2 ratios (from new Q^2 analysis, haplog 4453 and 4468):

$f_{C,r} = 0.0671 \pm 0.0134$ (20%) for prex-2 and 0.605 ± 0.121 (20%) for crex (haplog 4456 and 4470)

- A_{pv} analysis for prex-2 uses an equivalent formula:

$$A^{Pb}{}_{corr} = \frac{A^{dit}{}_{meas} - f_C A_C}{1 - f_C}$$

where $f_C = \frac{\text{rate\_C}}{(\text{rate\_C} + \text{rate\_Pb})} = 0.0629 \pm 0.00463$ for prex-2 obtained from simulation by Weibin

- The same simulation for crex kinematics doesn't work -- no xs tables for Pb at 2 GeV

--So we scaled Weibin's f_C simulation results for prex-2 to crex using FF^2/Q^2 ratios (from new Q^2 analysis, haplog 4453)

--The result was $f_C = 0.377 \pm 0.075$ (20%) for crex (see haplogs ~~4455~~, ~~4456~~, and 4470)

Dilution Factors and Asymmetry Correction

Ca data:

$$A^{Ca48}{}_{corr} = A^{dit}{}_{meas}(1 + f_{Ca40,r}) - f_{Ca40,r} A_{Ca40}$$

where $f_{Ca40,r} = \frac{\text{non\_Ca48}}{\text{Ca48}} = 0.0907 \pm 0.0018$ for crex (atomic fraction) obtained from isotopic analysis

- Purity correction uses same formula:

$$A^{Ca48}{}_{corr} = \frac{A^{dit}{}_{meas} - f_{Ca40} A_{Ca40}}{1 - f_{Ca40}}$$

where $f_{Ca} = \frac{\text{non\_Ca48}}{\text{(Ca48+non\_Ca48)}} = 0.0831 \pm 0.0017$ (atomic fraction) obtained from isotopic analysis

Impurity in Ca-48 dominated by Ca-40 (8%), then Ca-44 (0.19%)

Dilution/purity correction Summary

$$A_{corr} = Ad^{itme}{}_{as}(1 + f_{i,r}) - f_{i,r}A_i$$

Current Results
prex respin2 &
crex respin1

		corrected asymmetry (dithering)				purity correction			
		A_{corr} [ppb]	dA_{corr} stat [ppb]	dA_{beam} syst [ppb]	syst/stat %	A_{corr} [ppb]	dA_{corr} stat [ppb]	dA_{corr} syst [ppb]	Rate ratio ($f_{i,r}$)
PREX-2	Carbon-12	-5494	330	57	17%	-5494	330		Feb 2021
	Pb208	-24	128	57	44%	343	156	276	$f_{C,r} = 0.0671 \pm 0.0134$
	Ca40	-5295	290	214	74%	-5295	290		
CREX	Carbon-12	-8172	881	136	15%	-8172	881		
	Pb208	-2820	1630	94	6%	419	2748	686	$f_{C,r} = 0.6052 \pm 0.1210$
	Ca40	-8379	929	7	0.8%	-8379	929		
	Ca48	-7925	842	31	4%	-7884	923	583	$f_{Ca40,r} = 0.0907 \pm 0.0018$

from summer 2020 (prex -- respin2 and crex – prompt output)

PREX-2	Carbon-12	-5494	330	57	17%	-5494	330		Summer 2020
	Pb208	-24	128	57	44%	394	140	276	$f_{C,r} = 0.0765 \pm 0.0153$
	Ca40	-5295	290	214	74%	-5295	290		
CREX	Carbon-12	-8430	922	154	17%	-8430	922		
	Pb208	-3299	1739	86	5%	1278	3394	938	$f_{C,r} = 0.8920 \pm 0.1784$
	Ca40	-8700	977	3	0.3%	-8700	977		
	Ca48	-8220	892	90	10%	-8176	976	605	$f_{Ca40,r} = 0.0907 \pm 0.0018$

A_n calculation

$$A_n = \frac{A_{corr}}{P_b \langle \cos\phi \rangle}$$

Current Results

		A^{purity}_{corr} [ppb]	$\langle \cos\phi \rangle$	A_n [ppm]
PREX-2	Carbon-12	-5494	0.967	-6.35
	Pb208	343	0.966	0.40
	Ca40	-5295	0.964	-6.13
CREX	Carbon-12	-8172	0.969	-9.71
	Pb208	419	0.969	0.50
	Ca40	-8379	0.970	-9.94
	Ca48	-7884	0.970	-9.35

Results from summer 2020

A_{corr} [ppb]	$\langle \cos\phi \rangle$	A_n [ppm]
-5494	1/0.966	-5.93
394	1/0.969	0.43
-5295	1/0.974	-5.76
-8430	1/0.963	-9.34
1278	1/0.963	1.42
-8700	1/0.964	-9.66
-8176	1/0.964	-9.07

Polarimetry								
	Compton		Moller		Average			
Exp.	Polarization	Uncert	Polarization	Uncert	Polarization	Assigned uncertainty	Calc uncert	Relative uncert
PREX-2	88.5533	0.447	89.5	0.3	89.50	1.79	0.25	0.02
CREX	86.874	0.101	86.9	0.2	86.89	1.74	0.09	0.02

Errors

		Dilution/purity correction			A_n			
		A_{corr} [ppb]	dA_{corr} stat [ppb]	dA_{corr} syst [ppb]	A_n [ppm]	dA_n stat [ppm]	dA_n syst [ppm]	syst/stat
PREX-2	Carbon-12	-5494	330		-6.35	0.40	0.12	31%
	Pb208	343	156	276	0.40	0.18	0.28	156%
	Ca40	-5295	290		-6.13	0.36	0.24	67%
CREX	Carbon-12	-8172	881		-9.71	1.06	0.21	20%
	Pb208	419	2748	686	0.50	3.26	0.69	21%
	Ca40	-8379	929		-9.94	1.12	0.17	15%
	Ca48	-7884	923	583	-9.35	1.11	0.60	54%

$$dA_{corr}^{stat} = \sqrt{((1+f_{i,r}) \times dA_{meas})^2 + ((A_{meas} - A_i) \times df_{i,r})^2 + (f_{i,r} \times dA_i)^2}$$

$$dA_n^{stat} = |A_n| \text{ x } \sqrt{(dA_{corr}/A_{corr})^2 + (dP_b/P_b)^2}$$

$$dA_{corr}^{syst} = \sqrt{(0.05 \text{ x } A_{meas})^2 + (0.05 \text{ x } A_i)^2 + (f_{i,r} \text{ x } dAi)^2}$$

$$dA_n^{syst} = \sqrt{(0.02 \text{ x } A_{corr})^2 + (dA_{corr}^{syst})^2 + (dA_{beam}^{syst})^2}$$

non-linearity

New results compared to summer

		Current Results				Results from summer 2020			
		A_n				A_n			
		A_n [ppm]	dA_n stat [ppm]	dA_n syst [ppm]	syst/stat	A_n [ppm]	dA_n stat [ppm]	dA_n syst [ppm]	syst/stat
PREX-2	Carbon-12	-6.35	0.40	0.12	31%	-5.93	0.38	0.12	33%
	Pb208	0.40	0.18	0.28	156%	0.43	0.15	0.28	186%
	Ca40	-6.13	0.36	0.24	67%	-5.76	0.34	0.24	71%
CREX	Carbon-12	-9.71	1.06	0.21	20%	-9.34	1.04	0.23	22%
	Pb208	0.50	3.26	0.69	21%	1.42	1.93	0.94	49%
	Ca40	-9.94	1.12	0.17	15%	-9.66	1.10	0.17	16%
	Ca48	-9.35	1.11	0.60	54%	-9.07	1.01	0.63	63%

- You can find the new results in the google spreadsheet.

Q^2 update

Current Results

		Left Arm			Right Arm			Average			
Experiment	Target	Q2	Uncert	RMS	Q2	Uncert	RMS	Q2	Uncert (RMSs)	Q	uncert
PREX	Carbon-12	0.0068	0.000004	0.0014	0.0067	0.000005	0.0014	0.00673	0.0010	0.082	0.006
	Pb 8	0.0065	0.000005	0.0013	0.0064	0.000006	0.0013	0.00642	0.0009	0.080	0.006
	Pb 9	0.0065	0.000004	0.0013	0.0064	0.000005	0.0013	0.00642	0.0009	0.080	0.006
	Ca40	0.0068	0.000005	0.0014	0.0067	0.000006	0.0013	0.00675	0.0010	0.082	0.006
		Q2	Uncert	RMS	Q2	Uncert	RMS				
CREX	Carbon-12	0.0328	0.00002	0.0057	0.0334	0.00002	0.0063	0.0331	0.0043	0.182	0.012
	Pb	0.0319	0.00003	0.0052	0.0322	0.00003	0.0055	0.0320	0.0038	0.179	0.011
	Ca40	0.0306	0.00002	0.0044	0.0309	0.00002	0.0047	0.0308	0.0032	0.175	0.009
	Ca48	0.0304	0.00001	0.0043	0.0307	0.00002	0.0047	0.0306	0.0032	0.175	0.009

Results from summer 2020

Experiment	Target	Q2	Uncert	RMS	Q2	Uncert	RMS	Q2	Uncert (RMSs)	Q	uncert
PREX	Carbon-12	0.0065	0.0015		0.0066	0.0015		0.0066	0.0010	0.081	0.006
	Pb 8	0.0062	0.0013		0.0062	0.0013		0.0062	0.0009	0.079	0.006
	Pb 9	0.0062	0.0013		0.0063	0.0013		0.0062	0.0009	0.079	0.006
	Ca40	0.0067	0.0014		0.0066	0.0014		0.0066	0.0010	0.081	0.006
		Q2	Uncert	RMS	Q2	Uncert	RMS				
CREX	Carbon-12	0.0320	0.0055		0.0332	0.0072		0.0326	0.0045	0.181	0.013
	Pb	0.0312	0.0050		0.0319	0.0064		0.0315	0.0040	0.178	0.011
	Ca40	0.0300	0.0042		0.0303	0.0054		0.0301	0.0034	0.174	0.010
	Ca48	0.0297	0.0041		0.0300	0.0053		0.0299	0.0034	0.173	0.010

Summary

- Fixed a couple issues with spreadsheet:
  -- A_n calculation multiplied $\langle\cos\phi\rangle$ instead of divided by (caused ~5% increase in A_n)
  -- stat error propagation formula for dilution correction had incorrect term: $(dA_{meas} - dA_i)*df_{i,r}$ instead of $(A_{meas} - A_i)*df_{i,r}$
  [15% increase for prex-2 Pb and 3.5% increase for crex Pb; no changes for Ca]
  -- A_n stat error calc had mixed dither-corr *A's* (means) with dilution-corr *dA*'s…
- No changes in run selections. Prex-2 analyses were not redone—only carbon/pb rate ratio changed
- Re-examined and changed dilution or rate ratios:
  --new values obtained using simulation (for prex-2) and simulation combined with FF^2/Q^2 scaling (for crex)
  --prex-2 Pb $f_{C,\mathrm{r}}$ rate ratio factor went from 0.0765 to 0.0671; old values from average using calc from real data widths
  --crex Pb $f_{C,\mathrm{r}}$ rate ratio factor went from 0.890 to 0.605; old values from average using calc from real data widths
- Re-analyzed crex A_T dataset following the respin1:
  --all asymmetry means and stat errors decreased…why? We are getting ~10k more events per run passing cuts
  --results between regression and dithering very consistent
  --investigation finds pedestal change and 'mislabeled?' mapfile—causing shift in ok_cut throughput (and results)
  --So far respin1 is good, *but need to verify which ring setting is correct to use*. May need to quickly re-do anal
- Re-analyzed $\langle\cos\phi\rangle$ due to optics calibration changes since summer: changes in $\langle\cos\phi\rangle$ were double/triple checked
  --summer analysis used s0-hole problem runs, new analysis does not; also the pointing angle was changed
  --new distributions have ~asymmetry that was not there for summer analysis—caused by new database (db)
  --can reproduce old $\langle\cos\phi\rangle$ results with old db☺; the ~asymmetry goes away using old db with new runs
- Other 'small' considerations still under investigation: impact of inelastics and vertical pol. transport losses in 12 GeV era
- New analyses are ~complete. If future respin or need new ring setting, then crex asymmetry results will slightly change