A_n Analysis

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Outline

- New crex respin1 (compare summer to now)
- New crex rate ratios for D-Pb-D targets from simulation
- Error Analysis reworked to match Apv
- Summary

False Asymmetries

PREX-2:

Analysis from Ryan following respin-2; posted in haplog 4160 (July 2020); Final -- no changes for prex-2

	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)

$A_{false} = 0.25 * \Delta A$

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

Old

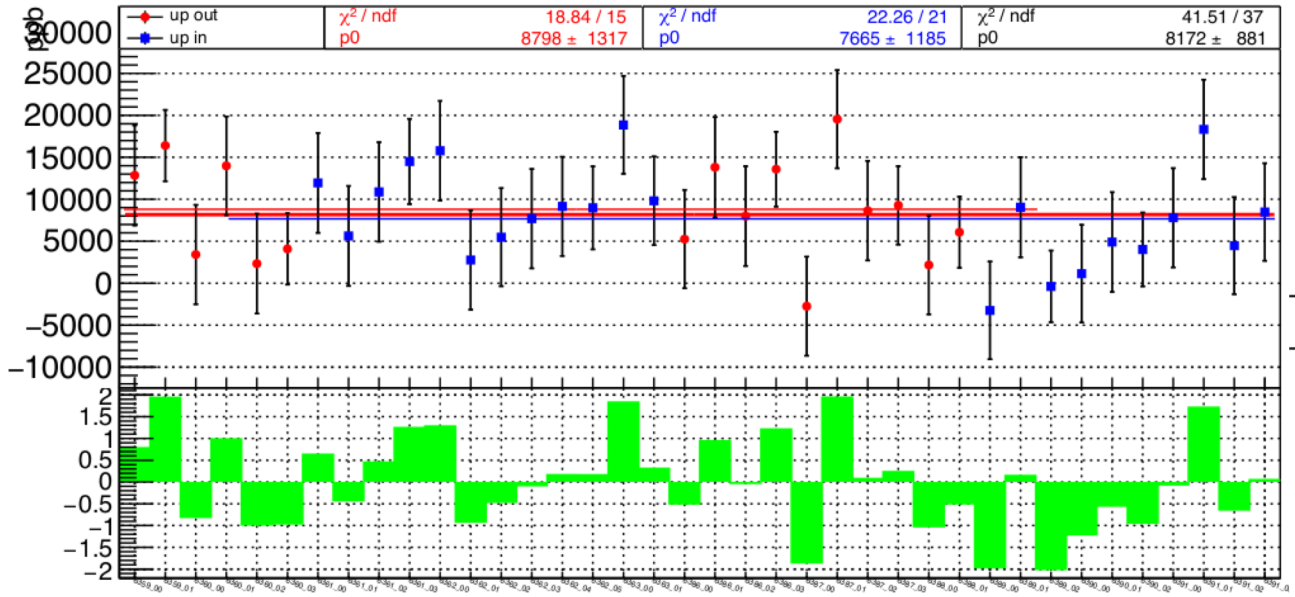
(Feb 2021 – respin1 output haplog 4464)

										$A_{false,\ dit}$
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

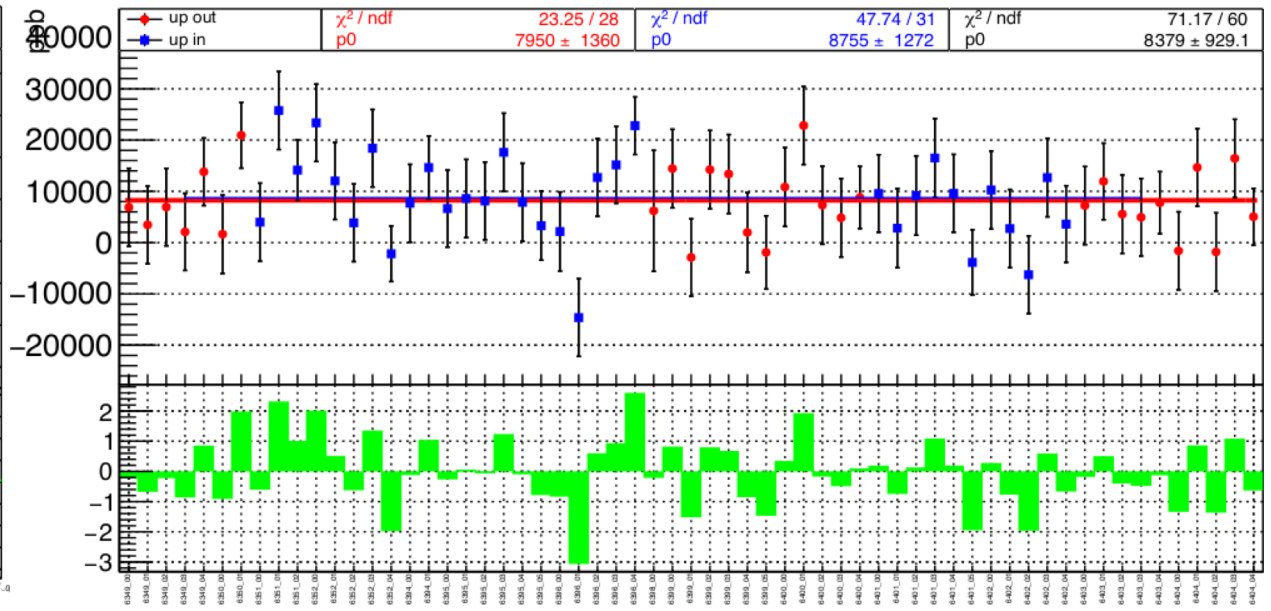
New

Respin1 CREX Asymmetries

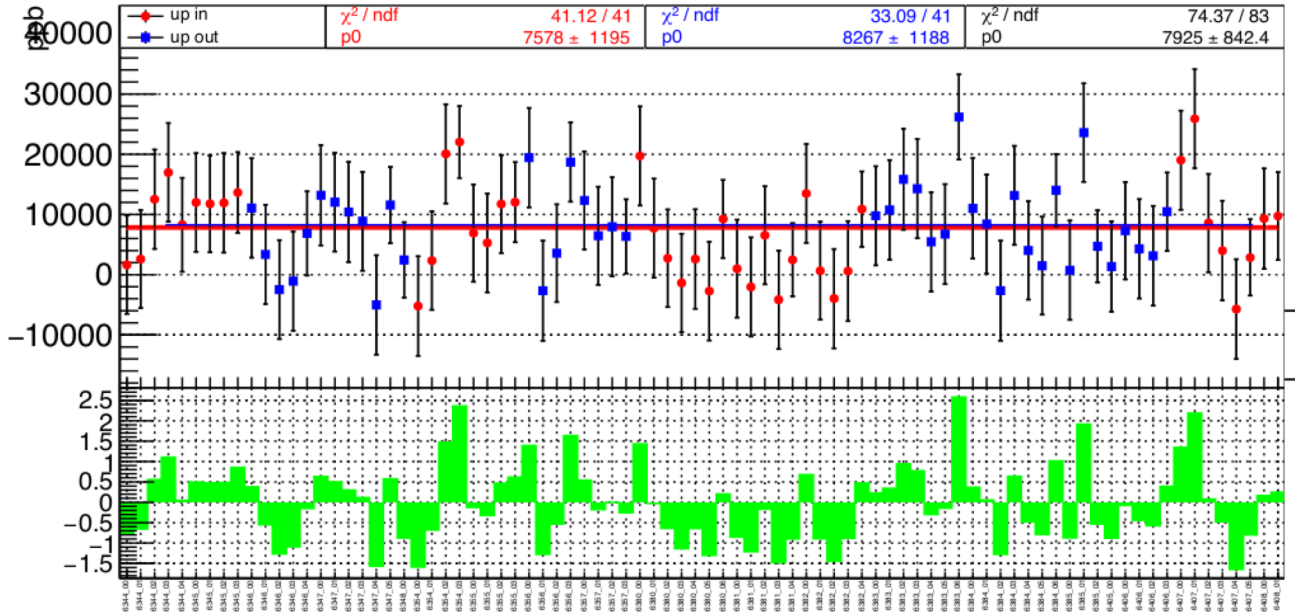
Carbon



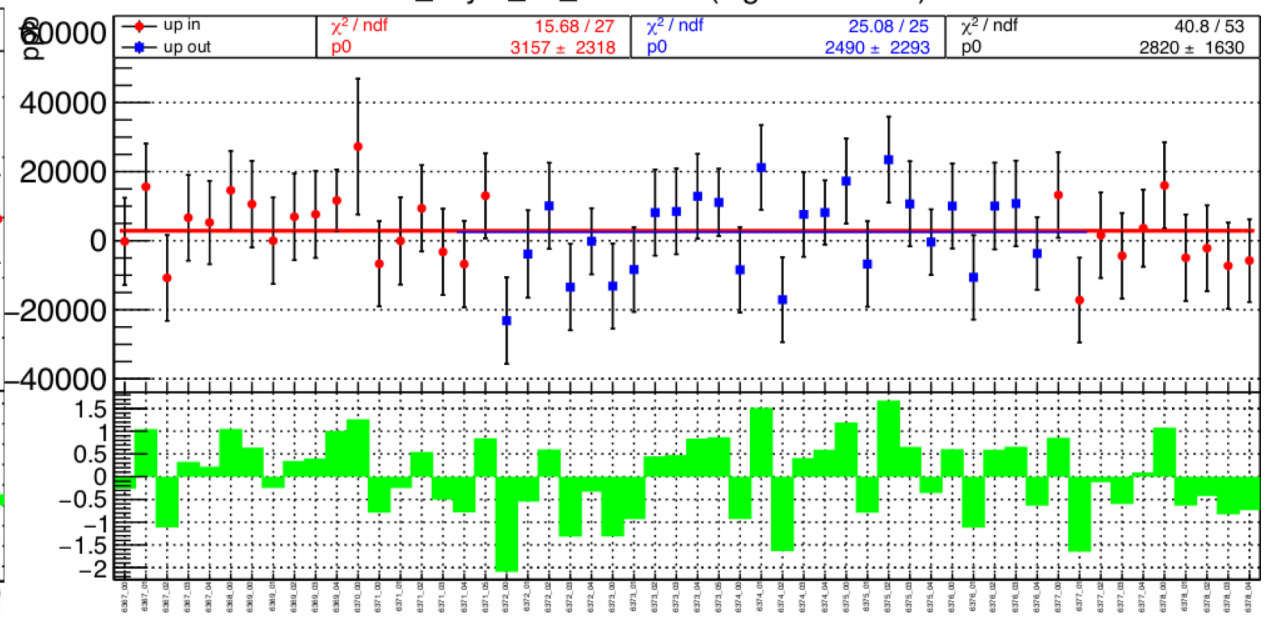
Ca-40



Ca-48



Pb



Changes in CREX results: Respin1 - Prompt (summer)

Target	Araw diff [ppb]	d(Araw diff) [ppb]	Araw diff [%]	d(Araw diff) [%]	Acorr diff [ppb]	d(Acorr diff) [ppb]	Acorr diff [%]	d(Acorr diff) [%]
Carbon-12	-185	320	-2.37	4.09	-258	270	-3.06	3.21
Pb208	-509	659	-17.24	22.3	-479	606	-14.5	18.4
Ca40	-361	392	-4.15	4.50	-321	302	-3.69	3.47
Ca48	-58.2	374	-0.74	4.76	-295	292	-3.59	3.55

- All raw and corrected asymmetry magnitudes decreased. Why?
  - Change in magnitudes are statistical (at 1σ level), but all same direction
  - Det. pedestals changed by approx. -2000 ch due to bcm ped re-calibration
    --resulting in a ~3 to 6% predicted decrease in measured asymm for all targets
  - Respin1 event cut changes give ~10^4 more events per run
- Shift in C and Ca targets consistent with predicted shift from pedestal change
- Shift in Pb results are 2x more than predicted, but within statistics
- Two back to back outlier Pb runs at the end deviate by -1.2 σ after accounting for changes due to pedestal shift. Cameron investigated this

Rate ratios and Asymmetry Correction

Pb data:

- Analysis uses the following formula for the carbon dilution correction:

From summer 2020: $A^{Pb}{}_{corr} = A^{dit}{}_{meas}(1 + f_C) - f_C A_C$ where $f_C = \frac{\text{rate\_C}}{\text{rate\_Pb}}$

$f_C = \frac{\text{rate\_C}}{\text{rate\_Pb}} = 0.0765 \pm 0.0153$ (20%) for PREX-2 and 0.89 ± 0.178 (20%) for CREX (haplog 4129)

--these values came from averages of analyses using calculated rates (FF/Q2) and rates from real data widths

March 2021:

$f_C = \frac{\text{rate\_C}}{\text{rate\_Pb}} = 0.0671 \pm 0.0057$ (8%) for PREX-2 and 0.64 ± 0.0512 (8%) for CREX (haplog to come)

--these values come from simulation (Method 3 in table)

Experiment	Method 1 f_C	Method 2 f_C	Current Method 3 f_C	summer avg(Meth1 + 2) f_C
PREX-Pb	0.0834	0.0696	0.0671	0.0765
CREX-Pb (respin1)	0.959	0.667	0.64	0.81
CREX-Pb (prompt)	1.08	0.704	-	0.892

Method 1: from real data widths **Method 2:** sim result scaled using $scale = \left\{ \frac{width_{C,PREX}}{width_{C,CREX}} \times \frac{width_{Pb+D,CREX}}{width_{Pb+D,PREX}} \right\}^2$

Method 3: Simulated results using Chuck's xs tables with focal plane momentum cut

Rate ratios and Asymmetry Correction

Ca data:

$$A^{Ca48}{}_{corr} = A^{dit}{}_{meas}(1 + f_{Ca40}) - f_{Ca40}A_{Ca40} \qquad \text{where } f_{Ca40} = \frac{\text{non\_Ca48}}{\text{Ca48}}$$

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

Impurity in Ca-48 dominated by Ca-40

Dilution/purity correction Summary

$$A_{corr} = A^{dit}{}_{meas}(1 + f_i) - f_i A_i$$

Column no longer used

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)
PREX-2	Carbon-12	-5494	330	57	17%	-5494	330		March 2021
	Pb208	-24	128	57	44%	343	136	276	$f_C = 0.0671 \pm 0.0134$
	Ca40	-5295	290	214	74%	-5295	290		
CREX	Carbon-12	-8172	881	136	15%	-8172	881		
	Pb208	-2820	1630	94	6%	606	2673	686	$f_C = 0.64 \pm 0.0512$
	Ca40	-8379	929	7	0.8%	-8379	929		
	Ca48	-7925	842	31	4%	-7884	919	583	$f_{Ca40} = 0.0907 \pm 0.0018$

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	$f_C = 0.0765 \pm 0.0153$
	Ca40	-5295	290	214	74%	-5295	290		
CREX	Carbon-12	-8430	922	154	17%	-8430	922		
	Pb208	-3299	1739	86	5%	1278	3394	938	$f_C = 0.892 \pm 0.1784$
	Ca40	-8700	977	3	0.3%	-8700	977		
	Ca48	-8220	892	90	10%	-8176	976	605	$f_{Ca40} = 0.0907 \pm 0.0018$

A_n calculation

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

Current Results

		A_{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	606	0.969	0.72
	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	0.30	0.02
CREX	86.874	0.101	86.9	0.2	86.89	1.74	0.09	0.02

Old Error Calculations

		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	141	276	0.40	0.16	0.28	172%
	Ca40	-5295	290		-6.13	0.36	0.24	67%
CREX	Carbon-12	-8172	881		-9.71	1.06	0.21	20%
	Pb208	606	2746	710	0.72	3.26	0.72	22%
	Ca40	-8379	929		-9.94	1.12	0.17	15%
	Ca48	-7884	923	583	-9.35	1.11	0.60	54%

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

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

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

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

non-linearity

New Error Calculations

		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	0.38	0.14	38%
	Pb208	343	136		0.40	0.16	0.08	50%
	Ca40	-5295	290		-6.13	0.34	0.28	83%
CREX	Carbon-12	-8172	881		-9.71	1.05	0.25	24%
	Pb208	606	2673		0.72	3.18	0.75	24%
	Ca40	-8379	929		-9.94	1.10	0.20	18%
	Ca48	-7884	919		-9.35	1.09	0.22	20%

$$dA_{corr}^{stat} = (1+f_i) \times dA_{meas}$$

$$dA_n^{stat} = \frac{1}{P_b \langle \cos\phi \rangle} (1+f_i) \times dA_{corr}$$

$$dA_n^{syst} = \frac{1}{P_b \langle \cos\phi \rangle} \sqrt{((A_{corr} - A_i) \times df_i)^2 + (f_i \times dA_i)^2 + \underbrace{(A_{corr} \times 0.02)^2}_{\text{non-linearity}} + (|A_{corr} - A_{raw}| \times 0.25)^2 + (pdP)^2}$$

$$pdP = [(1+f_i) \times A_{corr} - f_i \times A_i] \times dP_b/P_b$$

Error in $\langle \cos\phi \rangle$ is negligible

Error due to different beam corrections not included

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	0.38	0.14	38%	-5.93	0.38	0.12	33%
	Pb208	0.40	0.16	0.08	50%	0.43	0.15	0.28	186%
	Ca40	-6.13	0.34	0.28	83%	-5.76	0.34	0.24	71%
CREX	Carbon-12	-9.71	1.05	0.25	24%	-9.34	1.04	0.23	22%
	Pb208	0.72	3.18	0.75	24%	1.42	1.93	0.94	49%
	Ca40	-9.94	1.10	0.20	18%	-9.66	1.10	0.17	16%
	Ca48	-9.35	1.09	0.22	20%	-9.07	1.01	0.63	63%

- You can find the new results in the google spreadsheet. In the tab labelled ‘New Summary March 2021’

Summary

- Fixed a couple issues with spreadsheet from summer(nothing new since last presentation on 2/18):
  -- 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 rate ratios:
  --new values obtained from simulation for both PREX-2 and CREX
  --Simulated f_C's and those obtained from FF^2/Q^2 scaling are consistent, but both disagree with analysis using. real data widths
  --CREX Pb f_C rate ratio factor went from 0.890 to 0.64; old values from average using scaled rates and real data widths
- New respin1 CREX A_T dataset has been examined; shifts in data are understood; two Pb runs are still being scrutinized
  --Not sure what a future respin would entail… if we decide to change pedestals a little, then central values will 'jiggle'
- 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 since summer
- Small changes in Q^2 also occurred since summer due to above optics changes and s0-hole issues
- Residual tasks still remaining:
  --Put final polarization numbers in for PREX-2 (consistent with Apv paper) as well as final numbers for CREX
  --Finalize dilution factor analysis (get error on simulated rate ratio for CREX--soon). But real widths disagree
  --Finalize CREX respin1 Pb data (today?). So far, no smoking-gun reason to exclude last two runs (discussion)