A_T Analysis Update (final results)

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Outline from June 10, 2021
Update

- 1 minirun removed for PREX-2 Pb dataset (redid analysis)
- New non-linearity systematic calculation
- New CREX Moller polarization results
- Final CREX dilution factor (rate ratio)
- New beam correction systematic
- A_T results and summary

Outline for today

- New beam correction systematic (Robert's talk)
- New CREX A_T Compton results and ~final combined polarization
- Updated A_T results and summary

A_T Dataset

Combined (crex-respin2) FINAL											
		Average (HWP IN/OUT)		regression				dithering			
Experiment	Target	Araw [ppb]	d(Araw) [ppb]	A [ppb]	d(A) [ppb]	abs(Araw - A) [ppb]	dAbeam_corr [p	A [ppb]	d(A) [ppb]	abs(Araw - A) [ppb]	dAbeam_corr [ppb]
PREX-2(respin-2) haplog 4169 and 4155; 4549	Carbon-12	5267.8	740.8	5464.5	329.6	196.7	9.8	5493.9	330.0	226.1	11.3
	Pb208	-196.2	671.7	-0.9	127.0	195.3	9.8	-0.3	128.8	195.9	9.8
	Ca40	4439.2	1219.0	5276.3	288.3	837.0	41.9	5294.7	289.7	855.5	42.8
CREX(respin-2)	Carbon-12	7614.4	1040.3	8224.8	878.7	610.4	30.5	8166.8	879.5	552.4	27.6
	Pb208	2414.2	1741.4	2733.1	1608.4	319.0	15.9	2765.3	1610.1	351.1	17.6
	Ca40	8363.1	1198.5	8399.7	924.2	36.6	1.8	8405.0	925.6	41.9	2.1
	Ca48	7784.4	1074.7	7969.8	837.6	185.4	9.3	7916.9	839.2	132.5	6.6

Corrected Asymmetries (dithering)

Experiment	Target	Araw [ppb]	d(Araw) [ppb]	Acorr [ppb]	d(Acorr) [ppb]	d(Abeam) syst [ppb]	Previous d(Abeam) Abeam corr
PREX-2 (respin-2)	Carbon-12	-5268	741	-5494	330	11.3	56.5
	Pb208	196.2	672	0.257	129	9.8	49
	Ca40	-4439	1219	-5295	290	42.8	213.9
CREX (respin-2)	Carbon-12	-7614	1040	-8167	880	27.6	138.1
	Pb208	-2414	1741	-2765	1610	17.6	87.8
	Ca40	-8363	1198	-8405	926	2.1	10.5
	Ca48	-7784	1075	-7917	839	6.6	33.1

25% of correction

- Abeam correction systematic error uses new calculation: 0.05*abs(Araw - Acorr)

Beam Polarization for A_T

- 1 GeV A_T will use only the Moller results: from Apv publication numbers: 89.7 ± 0.80 %
  (found to be consistent with Moller measurements taken near time of A_T meas)
- 2 GeV A_T uses the both Moller and Compton measurements taken near time of A_T data collection:

  --From Moller: 86.9 ± 0.78 % overall (0.141 % from stat)

  --From Compton: 86.7 ± 0.63 % overall (0.10 % from stat)

CREX A_T Compton error table

Source	Relative Correction to Pol0	Contribution to Pol0 Uncertainty
Collimator Offset	-	0.53%
Laser Polarization	0.261%	0.44%
Gain Shift	-	0.15%
Model	0.12%	0.12%
Beam Energy	0.103%	0.05%
Nonlinearity	-	0.02%
Radiative Corrections	0.3%	Negligible
Statistics	-	**0.10%**
Total		**0.724%**

--We decided to simply average the two polarimetry results: both mean and overall error

--We also add an additional systematic error (0.14 %) in quadrature with overall average to account for dead-reckoning the Wein rotation angle when going vertical (assumed 3 deg precision, cos(3deg) = 99.86 %)

--2 GeV A_T combined polarization result: 86.78 ± 0.72 %

1 GeV A_T Systematic Errors

PREX-2 An Systematics:	Target	quantity	ppb	%		Previously (pdA_beam) ppb	%
	C	pdA_nonlinDet	30.38	0.48	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	0.61	0.01	= dA_nonlin/P/<cos>		
		pdA_beam	13.04	0.21	= dA_beam/P/<cos>	65.33	1.03
		pdP	-56.54	-0.89	= (A_corr/P/<cos>)*dP/P		
		Total:	65.50	1.03			
	D-Pb-D	pdA_nonlinDet	1.13	0.27	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	1.62	0.03	= dA_nonlin/P/<cos>		
		pdA_beam	11.31	2.66	= dA_beam/P/<cos>	65.41	16.52
		pdA_carbon	25.55	6.00	= f_carbon*dA_carbon/P/<cos>		
		pdf_carbon	36.14	8.49	= (A_corr - A_carbon)*df_carbon/P/<cos>		
		pdP	3.80	0.89	= [(1+f_carbon)*A_corr/P/<cos> - f_carbon*A_carbon/P/<cos>]*dP/P		
		Total:	45.88	10.78			
	Ca40	pdA_nonlinDet	25.67	0.42	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	1.21	0.02	= dA_nonlin/P/<cos>		
		pdA_beam	49.46	0.81	= dA_beam/P/<cos>	247.79	4.04
		pdP	-54.63	-0.89	= (A_corr/P)*dP/P/<cos>		
		Total:	78.05	1.27			

2 GeV A_T Systematic Errors

CREX An Systematics:	Target	quantity	ppb	%		Previously (pdA_beam) ppb	%
	C	pdA_nonlinDet	45.29	0.47	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	0.58	0.01	= dA_nonlin/P/<cos>		
		pdA_beam	32.85	0.34	= dA_beam/P/<cos>	161.81	1.67
		pdP	-80.37	-0.83	= (A_corr/P)*dP/P/<cos>		
		Total:	97.93	1.01			
	D-Pb-D	pdA_nonlinDet	14.35	2.31	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	0.02	0.00	= dA_nonlin/P/<cos>		
		pdA_beam	20.88	3.35	= dA_beam/P/<cos>	111.17	15.46
		pdA_carbon	636.77	102.32	= f_carbon*dA_carbon/P/<cos>		
		pdf_carbon	391.06	62.83	= (A_corr - A_carbon)*df_carbon/P/<cos>		
		pdP	5.15	0.83	= [(1+f_carbon)*A_corr/P/<cos> - f_carbon*A_carbon/P/<cos>]*dP/P		
		Total:	747.71	120.14			
	Ca40	pdA_nonlinDet	49.67	0.50	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	0.55	0.01	= dA_nonlin/P/<cos>		
		pdA_beam	2.49	0.02	= dA_beam/P/<cos>	8.81	0.09
		pdP	-82.60	-0.83	= (A_corr/P)*dP/P/<cos>		
		Total:	96.42	0.97			
	Ca48	pdA_nonlin	46.24	0.49	= dA_nonlin/P/<cos>		
		pdA_nonlinBCM	0.32	0.00	= dA_nonlin/P/<cos>		
		pdA_beam	7.87	0.08	= dA_beam/P/<cos>	36.46	0.39
		pdA_calcium	99.68	1.07	= f_ca40*dA_ca40/P/<cos>		
		pdf_calcium	1.04	0.01	= (A_phys - A_ca40)*df_ca40/P/<cos>		
		pdP	-77.38	-0.83	= [(1+f_ca40)*A_corr/P/<cos> - f_ca40*A_ca40/P/<cos>]*dP/P		
		Total:	134.63	1.44			

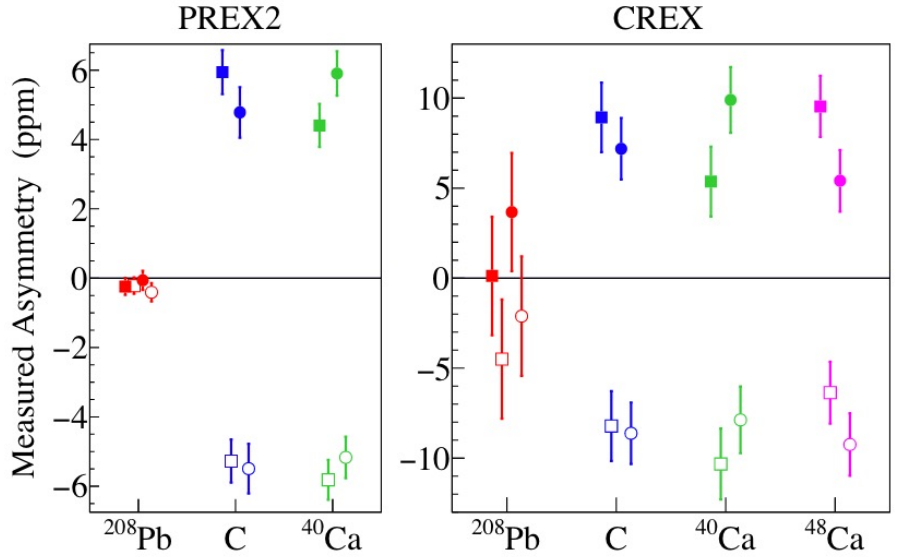
~Final A_T Results

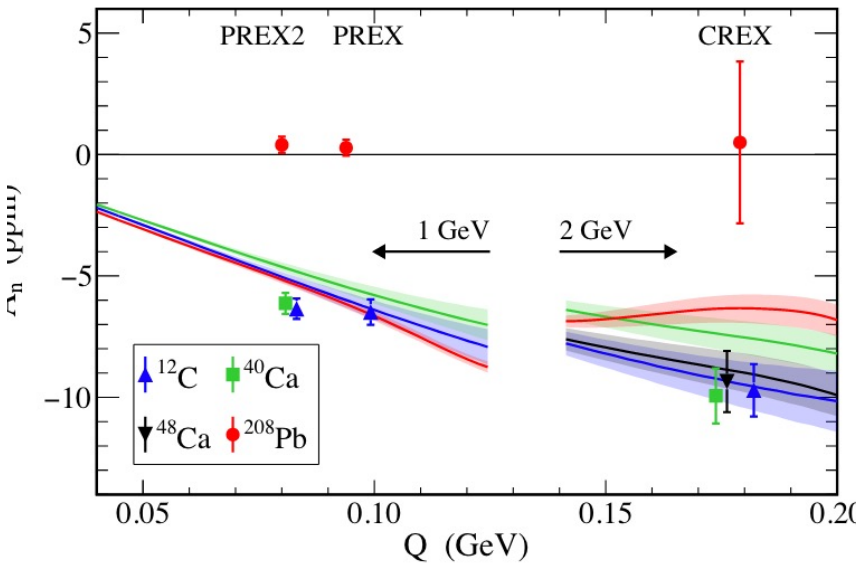
~Final Results

Theory predictions

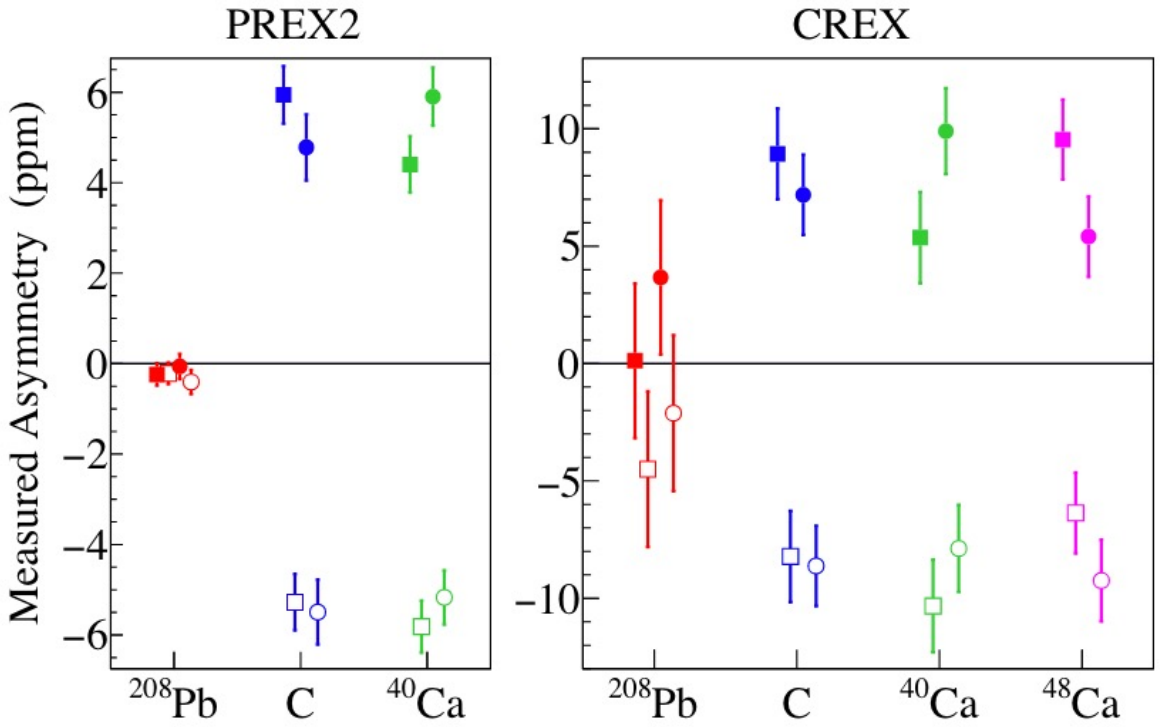
		A_T					A_T			
Experiment	Target	A [ppm]	d(A) stat [ppm]	d(A) syst [ppm]	syst/stat	d(A) tot [ppm]	A_{th} [ppm]	d(A_{th}) [ppm]	Deviation [ppm]	Deviation [#σ_{exp}]
PREX-2 (respin-2)	Carbon-12	-6.34	0.38	0.07	17%	0.39	-5.18	0.03	1.16	3.0
	Pb208	0.43	0.16	0.05	29%	0.17	-5.15	0.02	-4.72	-28
	Ca40	-6.12	0.34	0.08	23%	0.35	-4.75	0.06	1.37	3.9
CREX (respin-2)	Carbon-12	-9.71	1.05	0.10	9%	1.05	-9.56	0.35	0.15	0.14
	Pb208	0.62	3.15	0.75	24%	3.24	-6.33	1.31	-5.71	-1.8
	Ca40	-9.98	1.10	0.10	9%	1.10	-7.40	0.42	2.58	2.3
	Ca48	-9.35	1.09	0.13	12%	1.10	-8.83	0.5	0.52	0.5

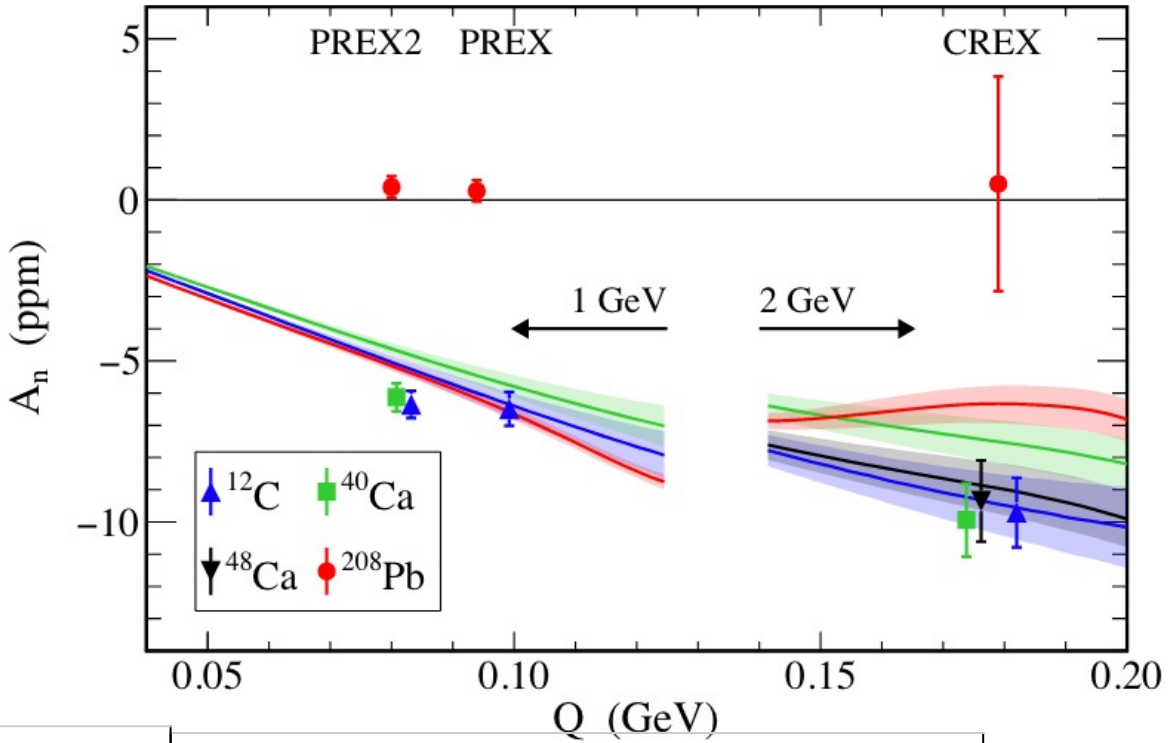
plots not exactly up to date





Plots (sorry not exactly up to date, but very close)





		~Final Results A_T					Theory predictions A_T			
Experiment	Target	A [ppm]	d(A) stat [ppm]	d(A) syst [ppm]	syst/stat	d(A) tot [ppm]	A_{th} [ppm]	$d(A_{th})$ [ppm]	Deviation [ppm]	Deviation [#σ_{exp}]
PREX-2 (respin-2)	Carbon-12	-6.34	0.38	0.07	17%	0.39	-5.18	0.03	1.16	3.0
	Pb208	0.43	0.16	0.05	29%	0.17	-5.15	0.02	-4.72	-28
	Ca40	-6.12	0.34	0.08	23%	0.35	-4.75	0.06	1.37	3.9
CREX (respin-2)	Carbon-12	-9.71	1.05	0.10	9%	1.05	-9.56	0.35	0.15	0.14
	Pb208	0.62	3.15	0.75	24%	3.24	-6.33	1.31	-5.71	-1.8
	Ca40	-9.98	1.10	0.10	9%	1.10	-7.40	0.42	2.58	2.3
	Ca48	-9.35	1.09	0.13	12%	1.10	-8.83	0.5	0.52	0.5

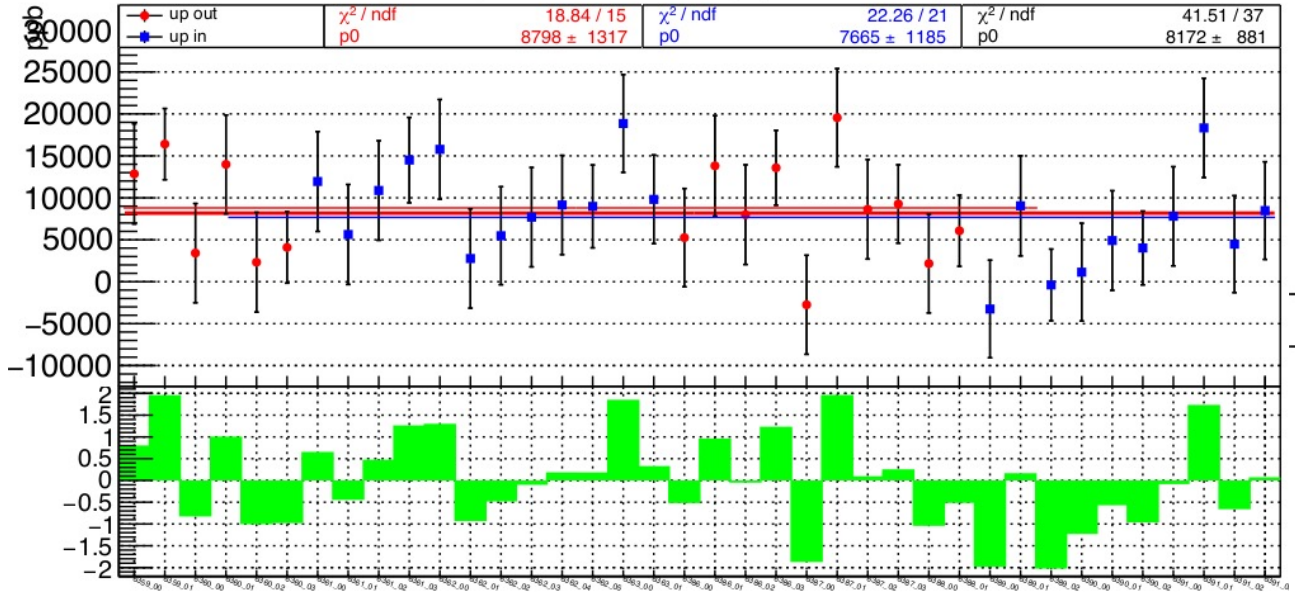
Summary

- Final analysis tasks completed and A_T results finalized (beam correction systematics and polarization)
- Some very minor lingering details to finalize:
  --how exactly we combine the 2 GeV polarimetry results; need to consider final Apv publication plans
  --the detector non-linearity systematic could be lower (0.5 → 0.3 %) for 2 GeV running-–again considering our plans for Apv
- Manuscript is nearly complete ; we plan to meet over the next couple weeks to finalize it, get feedback from collaborators and submit to PRL

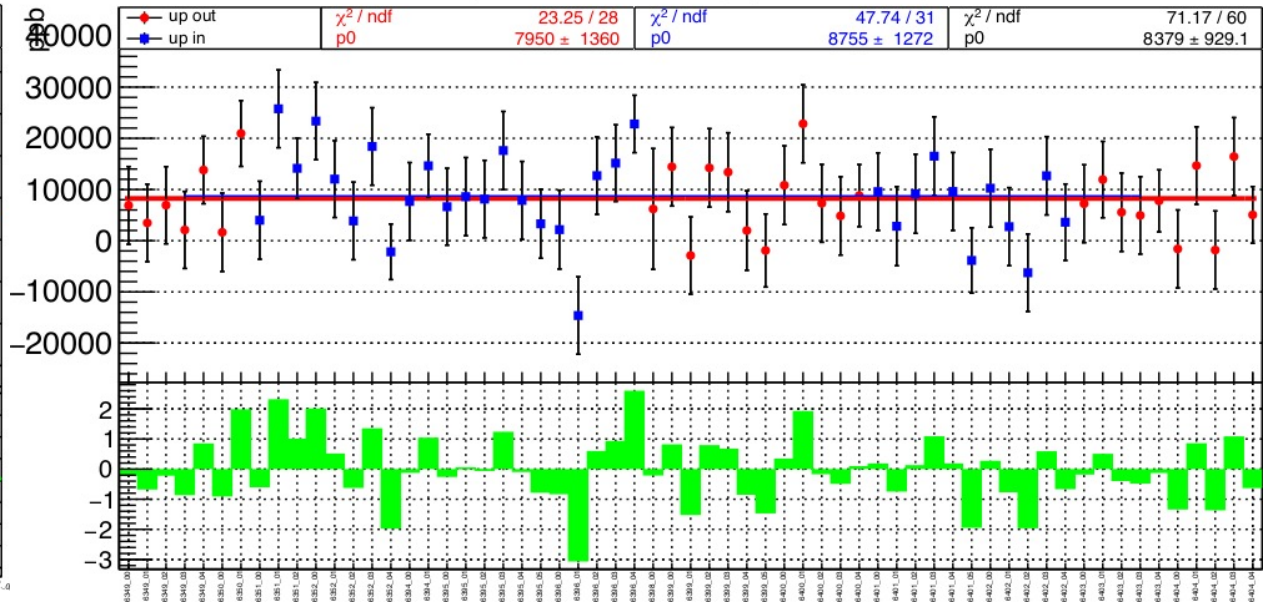
Some old slides (Backups)

Respin1 CREX Asymmetries

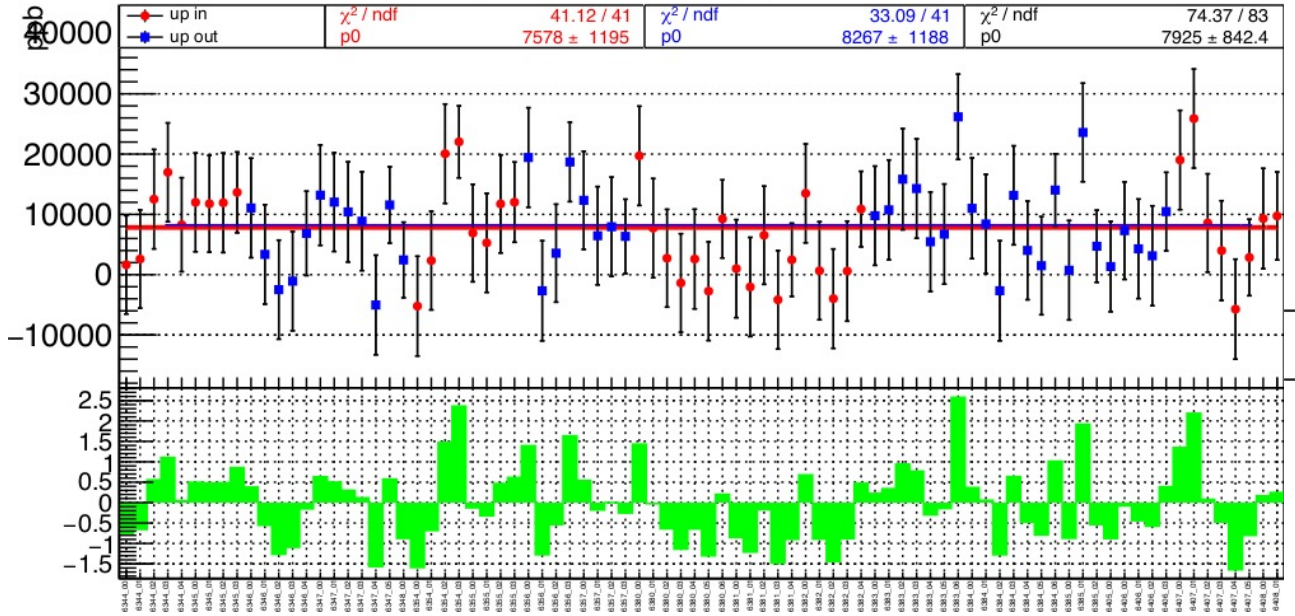
Carbon



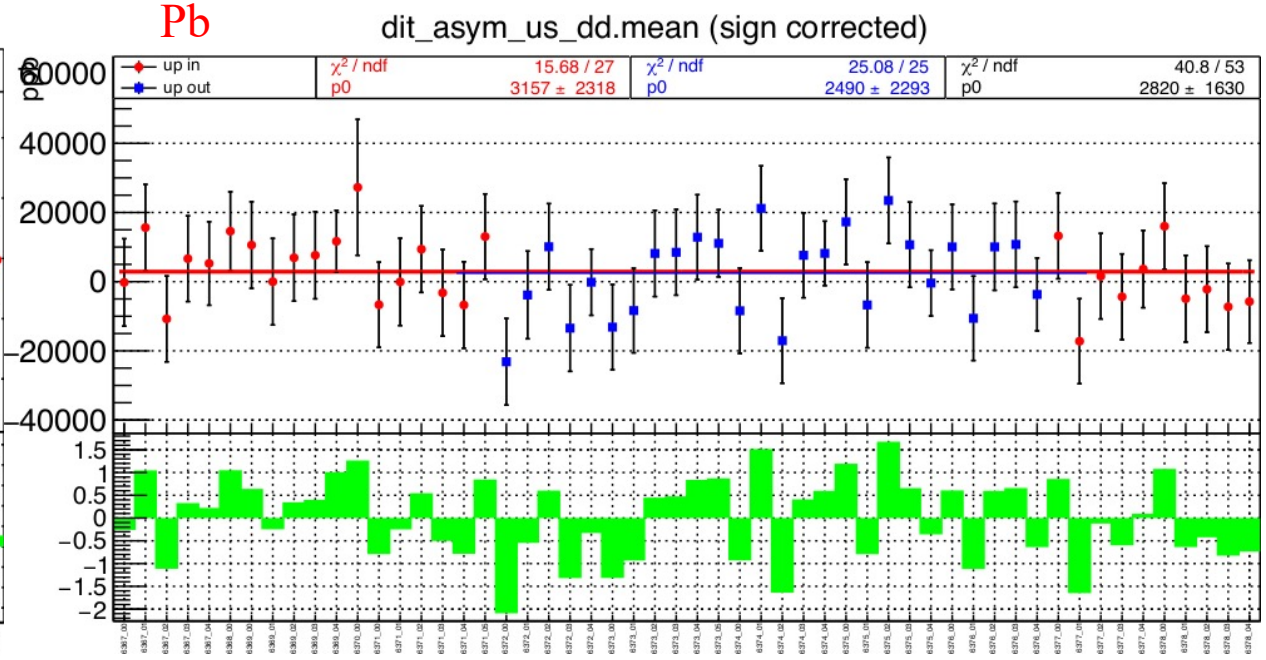
Ca-40



Ca-48



Pb



Error Calculations (from March 2021)

		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%

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

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

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

non-linearity

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

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

Error due to different beam corrections not included

A_T Dataset (June 2021)

		Average (HWP IN/OUT)		regression [units ppb]				dithering [units ppb]			
Experiment	Target	Araw [ppb]	d(Araw) [ppb]	A	d(A)	abs(Araw - A)	Abeam corr	A	d(A)	abs(Araw - A)	Abeam corr
PREX-2(respi	Carbon-12	5267.8	740.8	5464.5	329.6	196.7	49.2	5493.9	330	226.1	56.5
	Pb208	-196.2	671.7	-0.9	127	195.3	48.8	-0.3	128.8	195.9	49
	Ca40	4439.2	1219	5276.3	288.3	837	209.3	5294.7	289.7	855.5	213.9
CREX(respin-	Carbon-12	7614.4	1040.3	8224.8	878.7	610.4	152.6	8166.8	879.5	552.4	138.1
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	Ca40	8363.1	1198.5	8399.7	924.2	36.6	9.2	8405	925.6	41.9	10.5
	Ca48	7784.4	1074.7	7969.8	837.6	185.4	46.4	7916.9	839.2	132.5	33.1

- PREX-2(respin-2): from summer 2020 haplogs 4169 and 4155
- While investigating PREX-2 Aq, a bad minirun was found at very beginning of run 4117;

  --It was removed and then re-analyzed by Ryan (shown in blue); results are in haplog 4549

- New CREX results from Weibin posted in haplog 4524 following respin-2; no big changes
- Note that Abeam corrections in above table still use the original 0.25*(Araw-Acorr)

New non-linearity systematic calculation (June 2021)

- New correction separates the contributions from detector and BCM non-linearity
- The old calculation simply multiplied Acorr by 2.0 %

- Detector non-linearity uses 0.5 % x Araw

Det non linearity	
d(A) syst [ppb]	d(A) syst [%]
26	0.50%
1	0.50%
22	0.50%
38	0.50%
12	0.50%
42	0.50%
39	0.50%

AND

- BCM non-linearity uses 1.0 % x Aq

	New BCM Non Linearity Systematic			
	Target	Aq [ppb]	d(A) syst [ppb]	d(A) syst [%]
PREX-2	Carbon-12	-52.863	0.5	1.00%
	Pb208	140.602	1.4	1.00%
	Ca40	-104.763	1.0	1.00%
CREX	Carbon-12	50.09	0.5	1.00%
	Pb208	-1.61	0.0	1.00%
	Ca40	47.81	0.5	1.00%
	Ca48	27.35	0.3	1.00%
	Analysis done by Weibin: http://ace.phys.virginia.edu/HAPPEX/4544			

Slide from Eric and Don (June 2021)

A_T RUNS POLARIZATION (0.881%)

Moller measurements performed on 2/8 relevant to A_T running.

Summaries for groups 3022 (HWP-OUT) and 3023 (HWP-IN) are shown in the table.

Note: Pol% units are polarization percentages and not relative percentages.

Group	Date	iHWP	Polarization Measured	Stat Error [Pol%]	Syst Error [Pol%]
3022	2020-02-08	OUT	-86.98	0.203	0.766
3023	2020-02-08	IN	+86.83	0.197	0.764

Error-Weighted Mean Polarization [Pol%]	Stat Error [Pol%]	Syst Error [Pol%]
86.897	0.141	0.7655

Slide from Eric and Don (June 2021)

CREX A_T RUNS SYSTEMATICS (0.881%)

Source	Value	$\delta P/P$ (%)
A_{zz}	0.75421	0.16
Foil Polarization	0.08005	0.57
Dead Time Correction	0.148%	0.148
Accidental Correction	0.205%	0.041
Charge Normalization	0.029%	0.009
Null Asymmetry (Cu Foil)	0.0%	0.220
PITA Variation	—	0.06
Spin Precession (dP/P)	—	0.04
High Current Extrapolation	—	0.5
Bleedthrough	—	0.26
Slit Dependence	—	0.1
3° Wien Rotation Error	—	0.14
	Total	**0.881**

We have zero motivation to believe that there was anything other than a zero null asymmetry on this day consistent will all other measurements during PREX-II and CREX. This will remain unchanged.

PITA Variation over these two days was smaller than average so we will leave the systematic as the experimental average.

Bleed through was higher than average this day at 0.13%. Since Hall-C polarization is opposite that of Hall-A the value must be doubled.

Uncertainty in the angle rotation considering that the Wein angle rotation is good to +/-3 degrees (1-cos(3deg)=0.14%)

Dilution factors and Target Impurity (June 2021)

- CREX dilution factor for Pb finalized and taken from Weibin's simulation (same as for the PREX-2 result)
- The issues that were addressed/fixed were related to implementing Chuck's new XS tables correctly (fairly minor) but the BIG issue was we learned that:
  --Due to the radiative effects in the Pb (in between the diamond), the 'effective' radiation length of the diamond is lowered by ~0.5 (haplog: 4532)
  --After realizing this, the calculated rate ratio from data widths as well as (FF/Q)^2 scaling calculations agree with simulated results at 10 % level!

	Target impurity R_C/R_Pb	uncert	uncert [%]	Reference
Pb208 @ 1GeV	0.0671	0.0057	8%	from weibin's simulation (consistent with f_c used in Apv analysis)
Pb208 @ 2.2GeV	0.6089	0.0609	10%	from weibin's simulations. Consistent with calcs from data widths and FF/Q scaling at 10% level
Ca40	0.0003	0.0000	1%	https://prex.jlab.org/DocDB/0003/000306/001/Assay-2019.pdf
non-Ca48/(Ca48+non-Ca48) (atomic fraction)	0.0907	0.0018	2%	Ammount of non Ca48 0.08311570795 https://logbooks.jlab.org/entry/3769028
	The purity for Ca40/48 is atomic fraction			https://prex.jlab.org/DocDB/0003/000306/001/Assay-2019.pdf
				https://logbooks.jlab.org/files/2016/03/3386944/Assay%20Ca-48%20900242.pdf