Transverse Asymmetry Measurement in PREX-II and CREX

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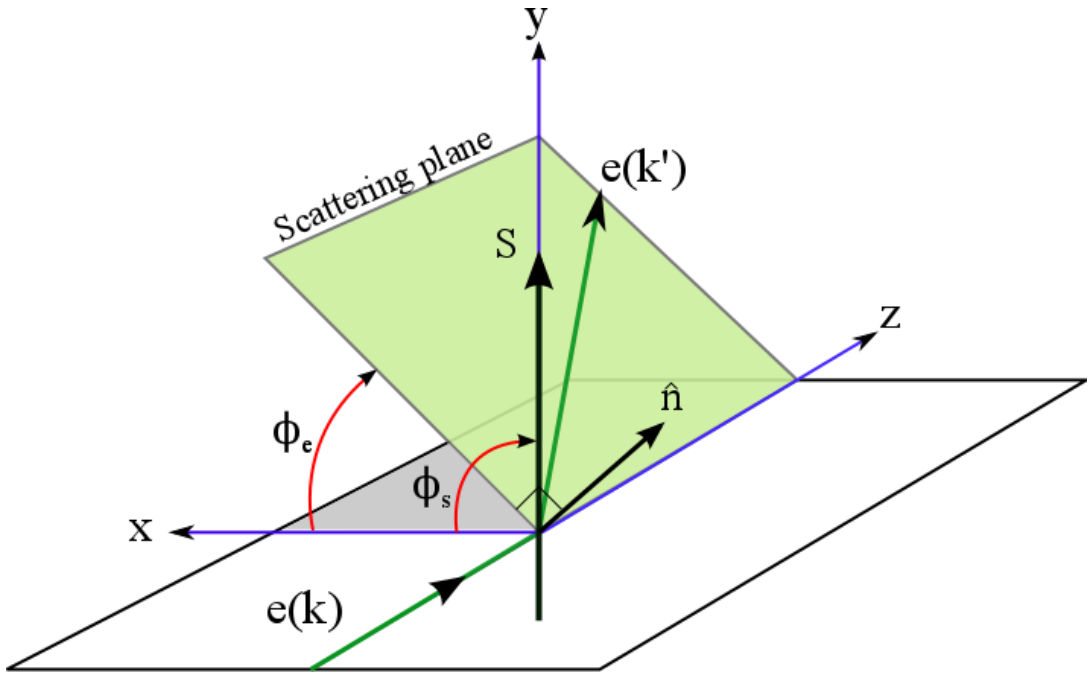
Motivation

- A systematic uncertainty to PREX/CREX data
- Verify the Two Photon Exchange (TPE) theory

What is Transverse Asymmetry



$$\mathcal{A}_{meas}(\phi_e) = \mathcal{A}_n(\vec{S}_e \cdot \hat{n}) = \mathcal{A}_n|\vec{S}_e|\sin(\phi_e - \phi_s)$$

- $\hat{n} \equiv \frac{(\vec{k}\times\vec{k}')}{|\vec{k}\times\vec{k}'|}$: normal direction of the scattering plane
- $\mathcal{A}_n$: analyzing power
- Azimuthal angle (ϕ_e) dependent
- Choose ϕ_s to be: 0° (horizontal) or 90° (**vertical**)

Basic Info

runs:

PREX-II

- ^{12}C (@70 μA) 4106-4109, 4131-4133
- ^{40}Ca (@70 μA) 4123-4127
- ^{208}Pb (@70 μA) 4110-4119, 4128-4130

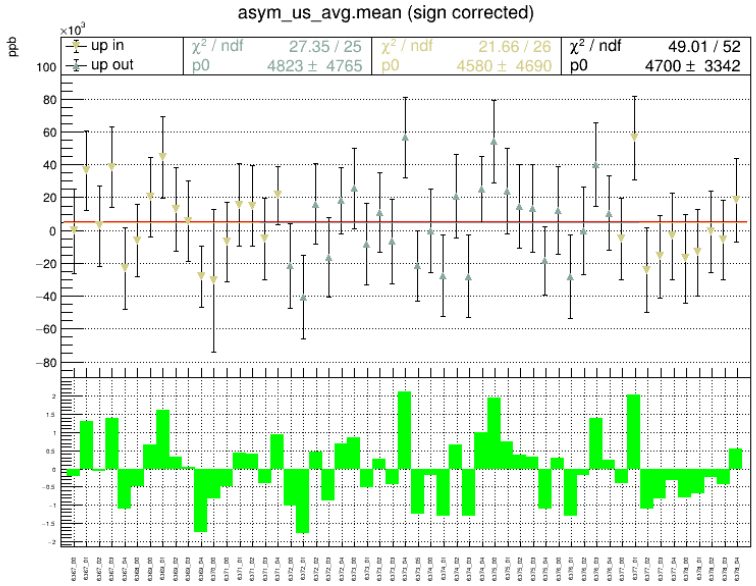
CREX

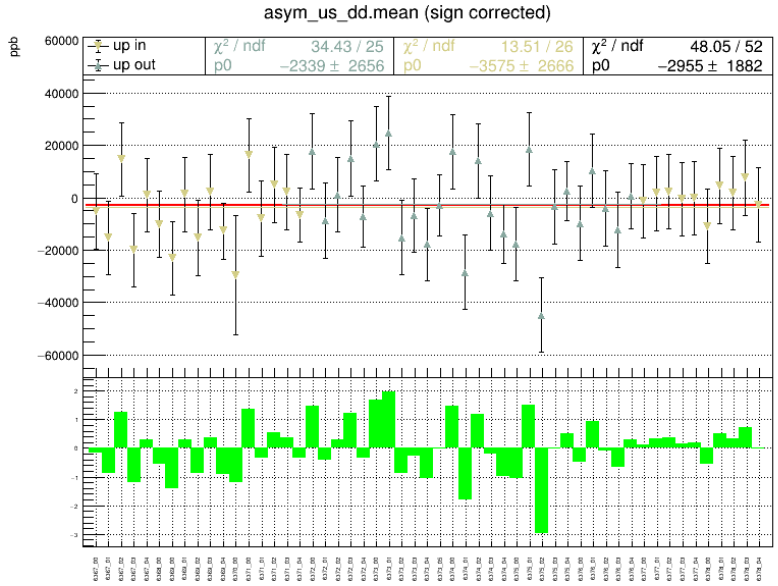
- ^{12}C (@150 μA) 6359-6363, 6386-6391
- ^{40}Ca (@150 μA) 6349-6352, 6394-6396, 6398-6404
- ^{48}Ca (@150 μA) 6344-6348, 6380-6385, 6405-6408
- ^{208}Pb (@70 μA) 6367-6378

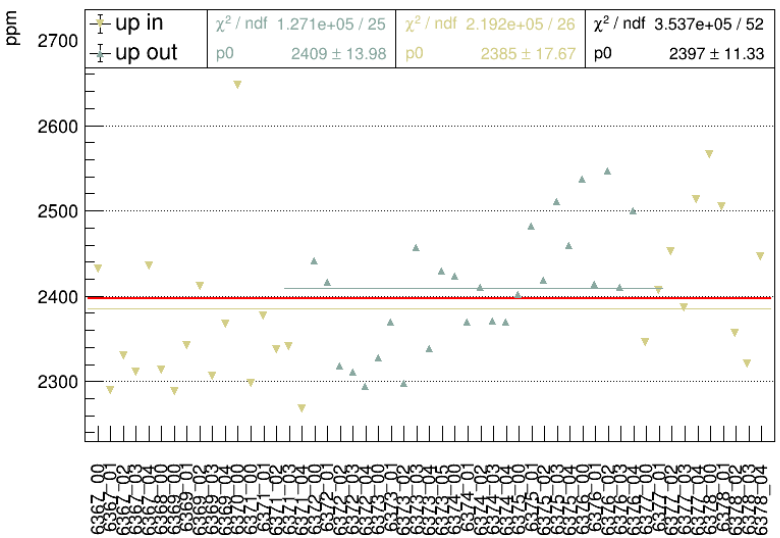
cuts:

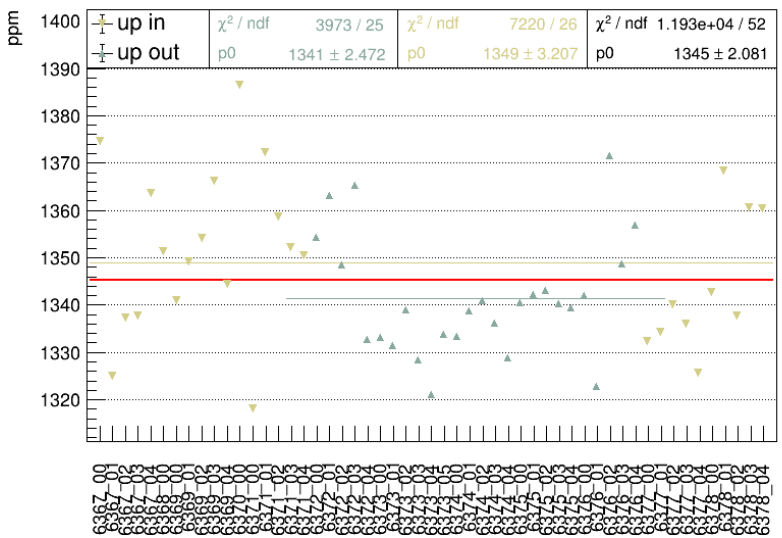
- bcm_an_us $>$ 120 uA for 150 uA runs
- bcm_an_us $>$ 50 uA for 70 uA runs

Raw Data: Minirun Distribution of ^{208}Pb (CREX)

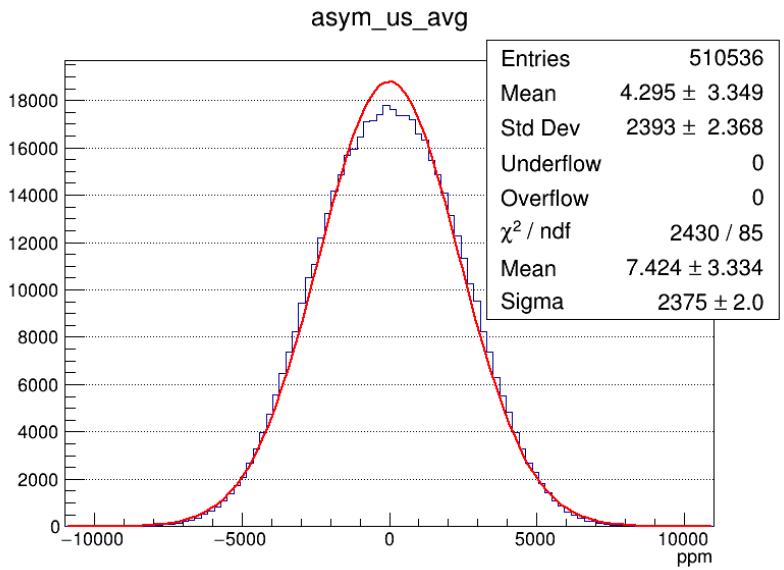


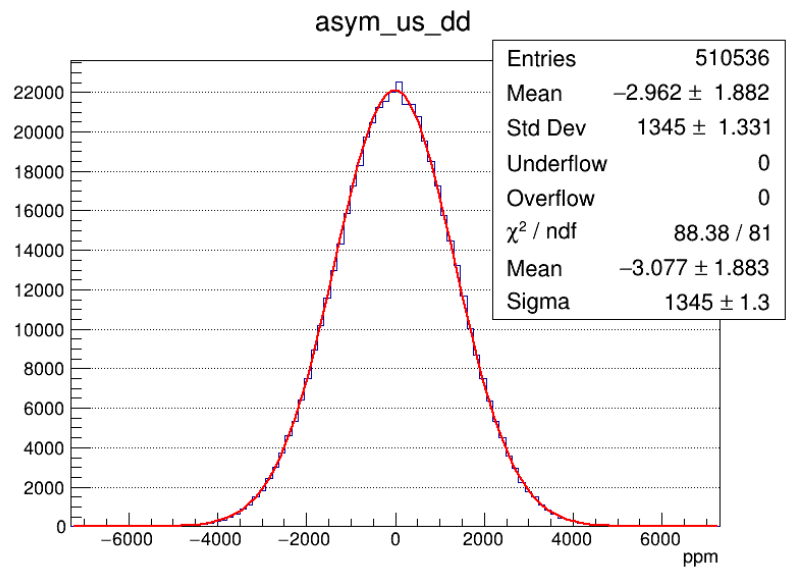


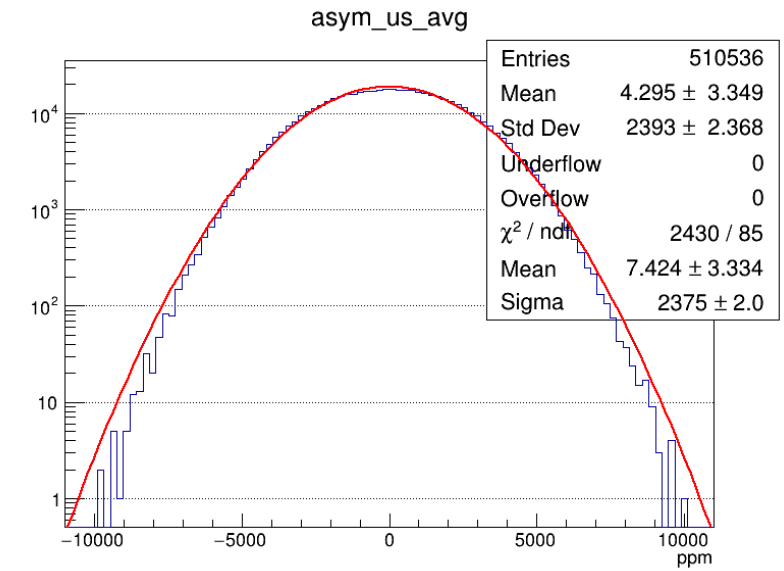


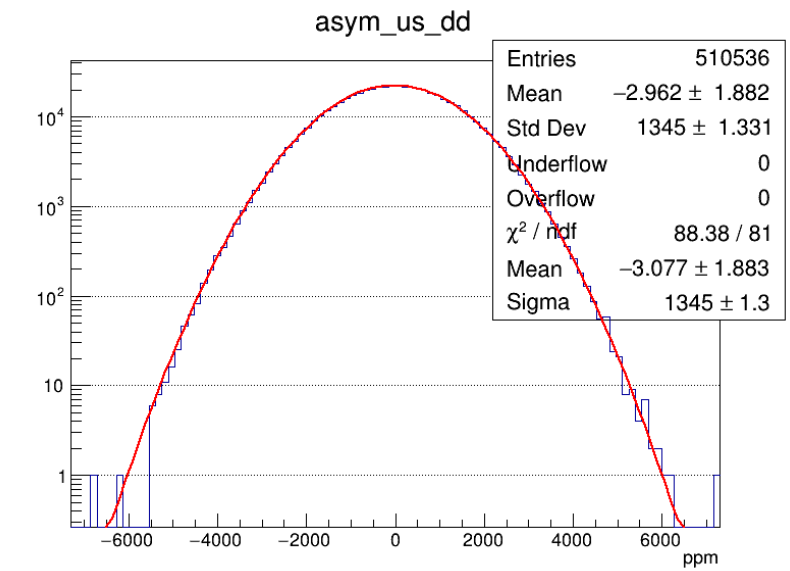


Raw Data: Mulplot of ^{208}Pb (CREX)







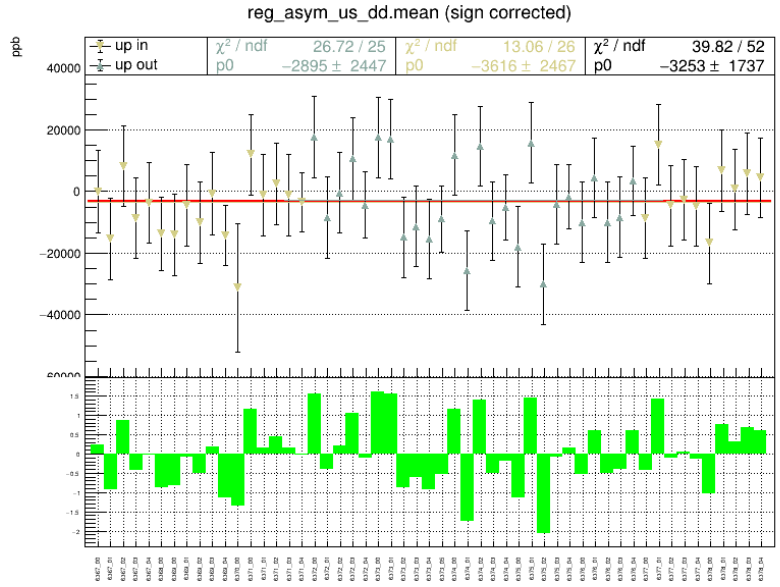


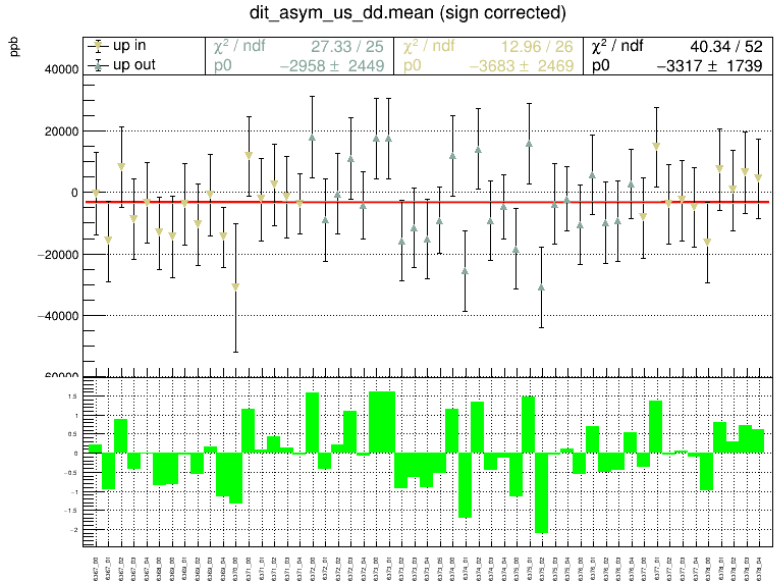
Corrections

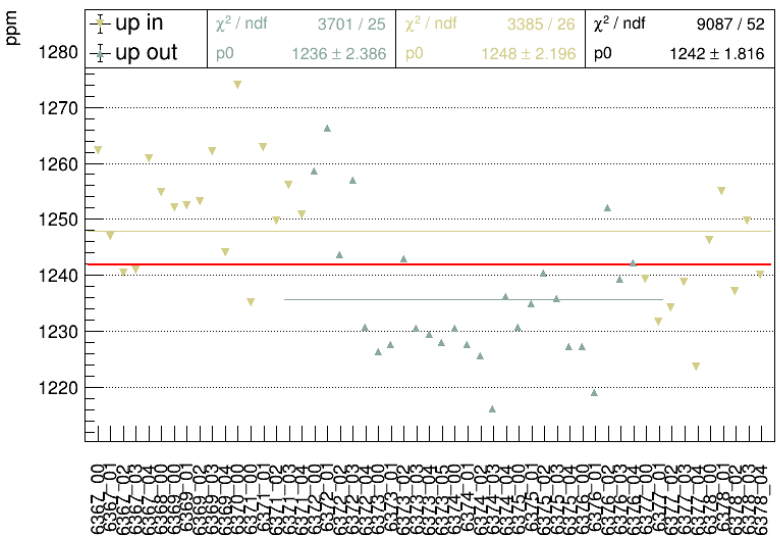
$$\mathcal{A}_{\text{corr}} = \mathcal{A}_{meas} - \sum_{i=1}^{5} B_i \Delta x_i$$

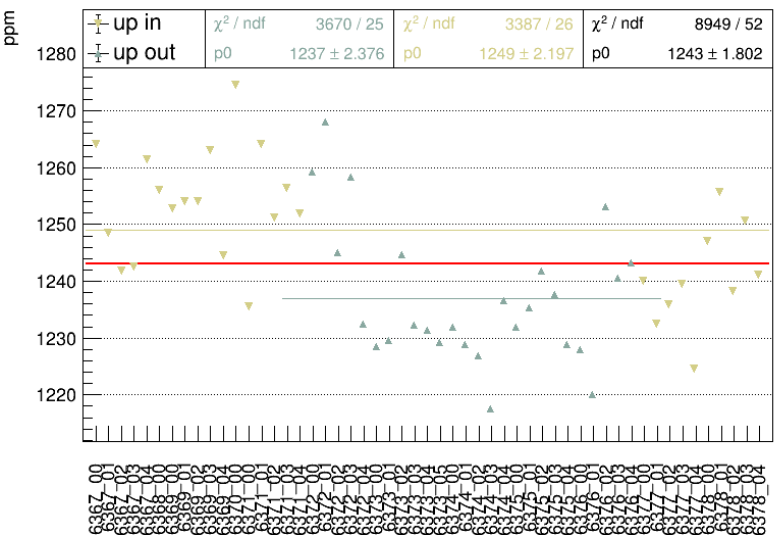
- Regression: based on natural beam fluctuation, minimize the χ^2 of a given fit
- Dithering: modulate the beam deliberately, and then measure the detector (monitor) response

Corrected Data (Minirun): ^{208}Pb (CREX)

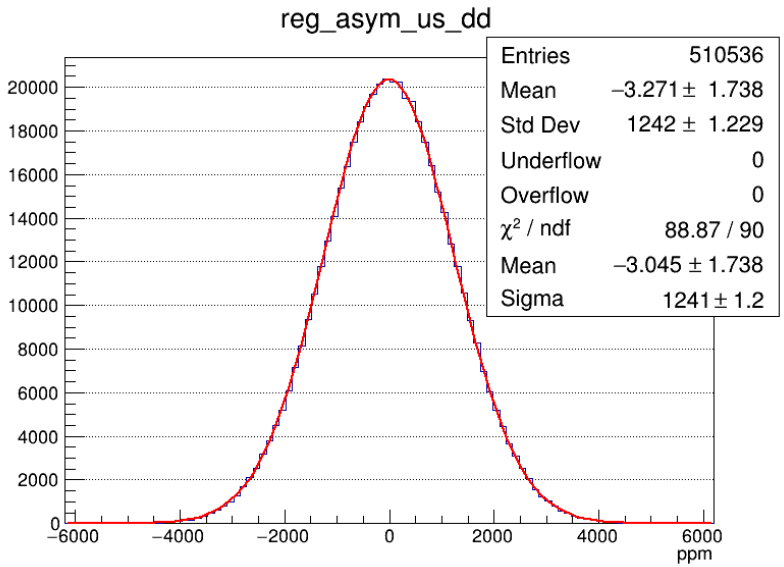


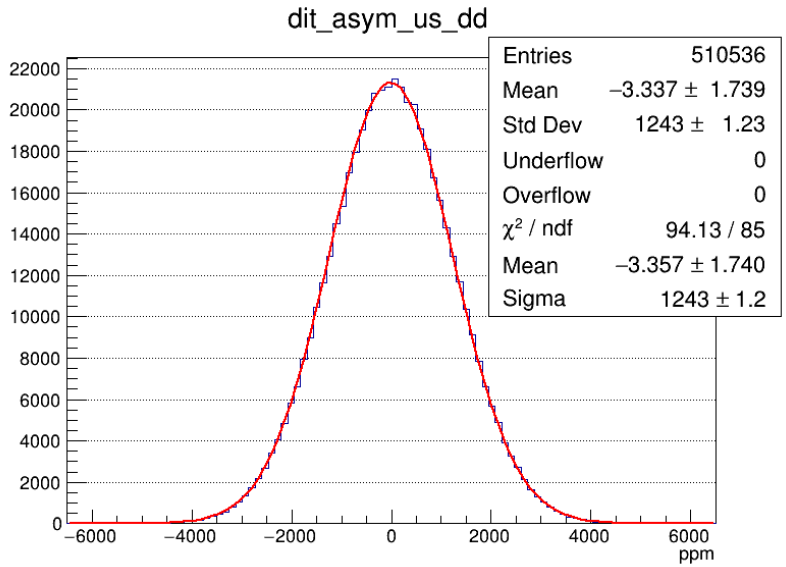


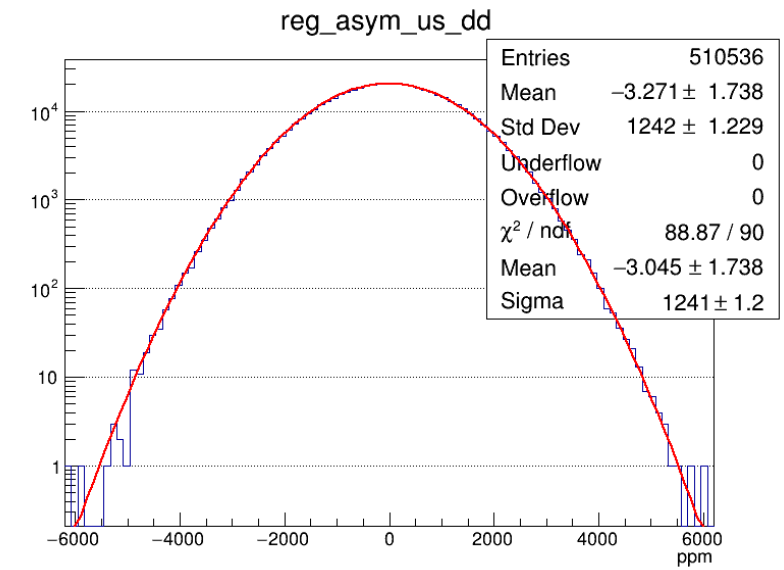


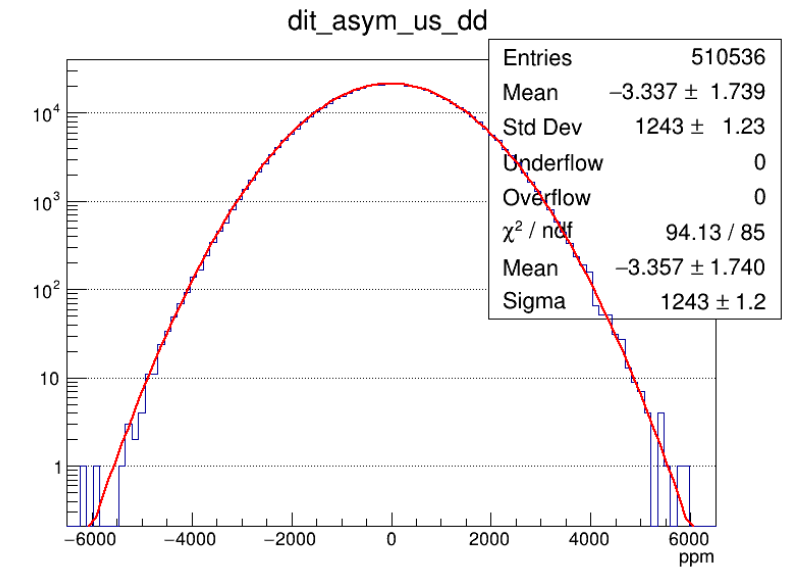


Corrected Data (Mulplot): ^{208}Pb (CREX)









Summary of Asym Data (CREX)

Target	Raw (ppb)	Regression (ppb)		Dithering (ppb)	
	A	A	$\lvert\Delta A\rvert$	A	$\lvert\Delta A\rvert$
C	-7813 $\pm$ 1090	-8528 $\pm$ 920.6	715	-8430 $\pm$ 921.5	617
Ca40	-8711 $\pm$ 1265	-8757 $\pm$ 975.2	46	-8700 $\pm$ 977	11
Ca48	-7860 $\pm$ 1142	-8283 $\pm$ 889.5	423	-8220 $\pm$ 891.6	360
Pb	-2955 $\pm$ 1882	-3253 $\pm$ 1737	298	-3317 $\pm$ 1739	352

Mean and RMS of asym_us_dd (CREX)

mean

Target	Minirun Average (ppb)			Mulplot (ppb)		
	raw	reg	dit	raw	reg	dit
C	-7813 ± 1090	-8528 ± 920.6	-8430 ± 921.5	-7799 ± 1091	-8541 ± 920.6	-8433 ± 921.6
Ca40	-8711 ± 1265	-8757 ± 975.2	-8700 ± 977	-8814 ± 1267	-8738 ± 975.3	-8680 ± 977.2
Ca48	-7860 ± 1142	-8283 ± 889.5	-8220 ± 891.6	-7821 ± 1143	-8302 ± 889.6	-8243 ± 891.7
Pb	-2955 ± 1882	-3253 ± 1737	-3317 ± 1739	-2962 ± 1882	-3271 ± 1738	-3337 ± 1739

rms

Target	Minirun Average (ppm)			Mulplot (ppm)		
	raw	reg	dit	raw	reg	dit
C	686.5	579.3	579.9	686.1	579.2	579.8
Ca40	963.6	741.1	742.6	962.5	741.1	742.5
Ca48	1034	804.9	806.9	1034	805.2	807.1
Pb	1345	1242	1243	1345	1242	1243

Further Correction: Purity Correction for ^{208}Pb

- The Pb target is actually a D-Pb-D sandwich
- do the correction based on scattering rate of each component:

$$width = 1/\sqrt{n \times t \times r}$$

  - n is the number of multiplet: 8 (4) for PREX-II (CREX)
  - t is the time interval of each helicity window: 1/240 (1/120) for PREX-II (CREX)

target	I (μA)	width (ppm)	cor. width (ppm)	width @70 μA (ppm)	R (MHz)
C-run4133	87.8	143.4	132.939	148.885	1353.373
Pb/D-slug64	70.6	94.4	82.210	82.562	4401.140
C-run6360	148.2	597.7	596.280	867.611	39.854
Pb/D-run6370	65.1	1269.8	1269.132	1223.907	20.027

$$f = \frac{R_D}{R_{Pb}} = \frac{\frac{t_D}{t_C} * R_C}{R_{Pb/D} - R_D} = \begin{cases} 0.082 & \text{PREX-II} \\ 0.960 & \text{CREX} \end{cases}$$

Purity Correction for Ca

- The impurity of ^{40}Ca is negligible
- The ^{48}Ca target is a stacked target composed of 3 pieces from 2 different sources due to the target melting accident
  - ^{48}Ca : 91.688%
  - ^{40}Ca : 8.004%
  - ^{44}Ca : 0.193%

Element: Calcium
Symbol: Ca
Isotope: 40
Series: JW
Batch: 118740

ISOTOPIC ANALYSIS

Isotope	Atomic Percent	Precision plus/minus
40	99.9650	0.01000
42	0.0090	0.00300
43	0.0020	0.00100
44	0.0220	0.00300
46	<.001	0.00000
48	0.0020	0.00100

Element: Calcium
Symbol: Ca
Isotope: 48
Series: LO
Batch: 140042

ISOTOPIC ANALYSIS

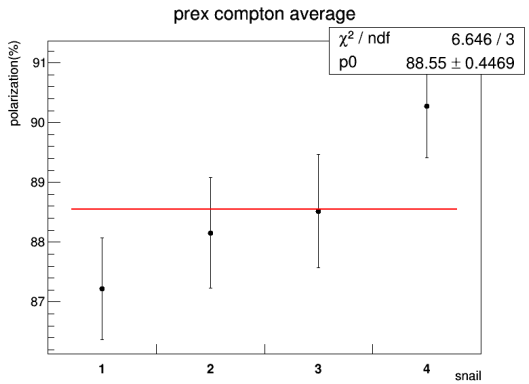
Isotope	Atomic Percent	Precision plus/minus
40	3.8400	0.02000
42	0.0500	0.01000
43	<.01	0.00000
44	0.1100	0.01000
46	<0.01	0.00000
48	95.9900	0.02000

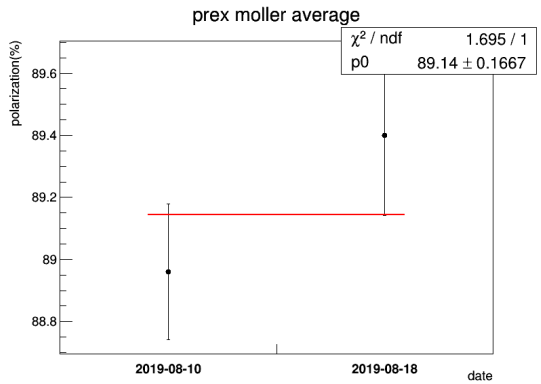
Element: Calcium
Symbol: Ca
Isotope: 48
Series:
Batch: 900242

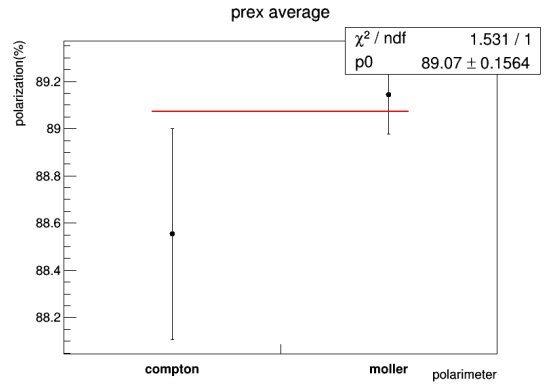
ISOTOPIC ANALYSIS

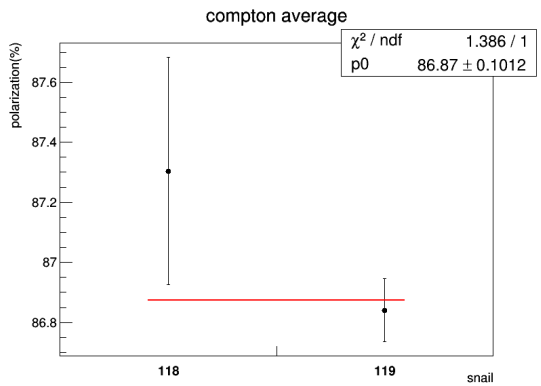
Isotope	Atomic Percent	Precision plus/minus
40	9.60	0.11000
42	0.12	0.00100
43	0.01	0.00100
44	0.225	0.00700
46	<0.01	0.00000
48	90.04	0.13000

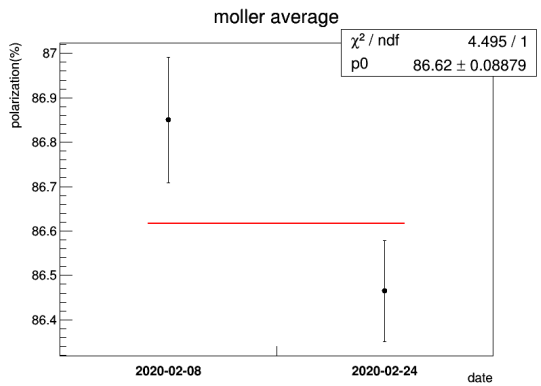
Polarization

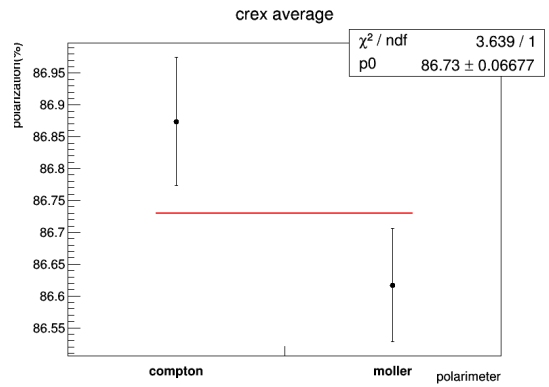




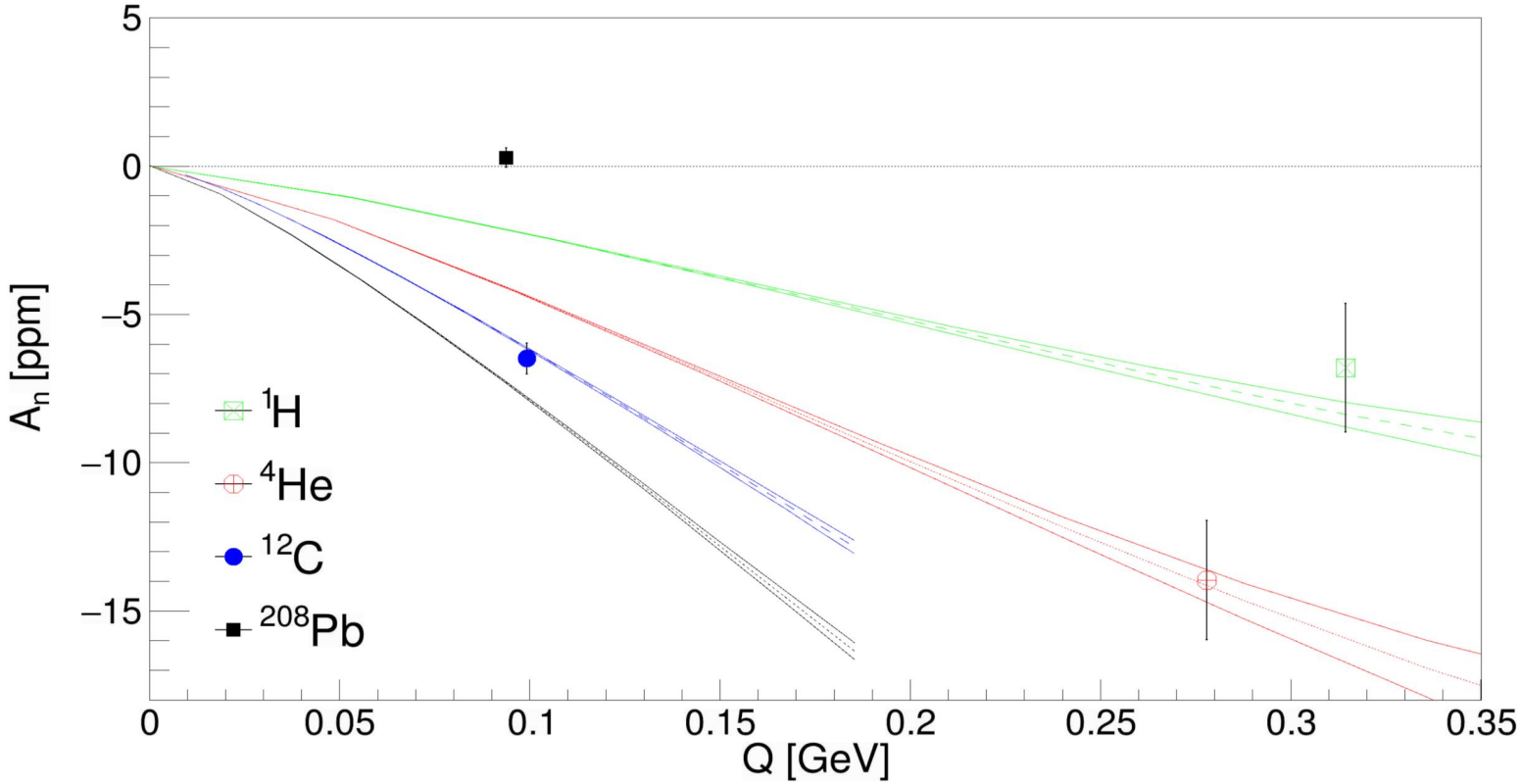








PREX-I and HAPPEX Result [PRL 109, 192501 (2012)]



The newset result from PREX-II and CREX is preliminary, so is not shown right now.

Backup

Impurity Correction

$$\mathcal{A}_{meas} = \frac{N_0\mathcal{A}_0 + \sum_{i=1}^{k} N_i\mathcal{A}_i}{N_0 + \sum_{i=1}^{k} N_i}$$

$$\Downarrow$$

$$(1 + \sum_{i=1}^{k} \frac{N_i}{N_0})\mathcal{A}_{meas} = \mathcal{A}_0 + \sum_{i=1}^{k} \frac{N_i}{N_0}\mathcal{A}_i$$

$$\Downarrow (f_i = N_i/N_0)$$

$$\mathcal{A}_0 = (1 + \sum_{i=1}^{k} f_i)\mathcal{A}_{meas} - \sum_{i=1}^{k} f_i\mathcal{A}_i$$

Where N is the counting rate of each component