CREX

(Ca Radius EXperiment)

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(on the behalf of the CREX Collaboration)

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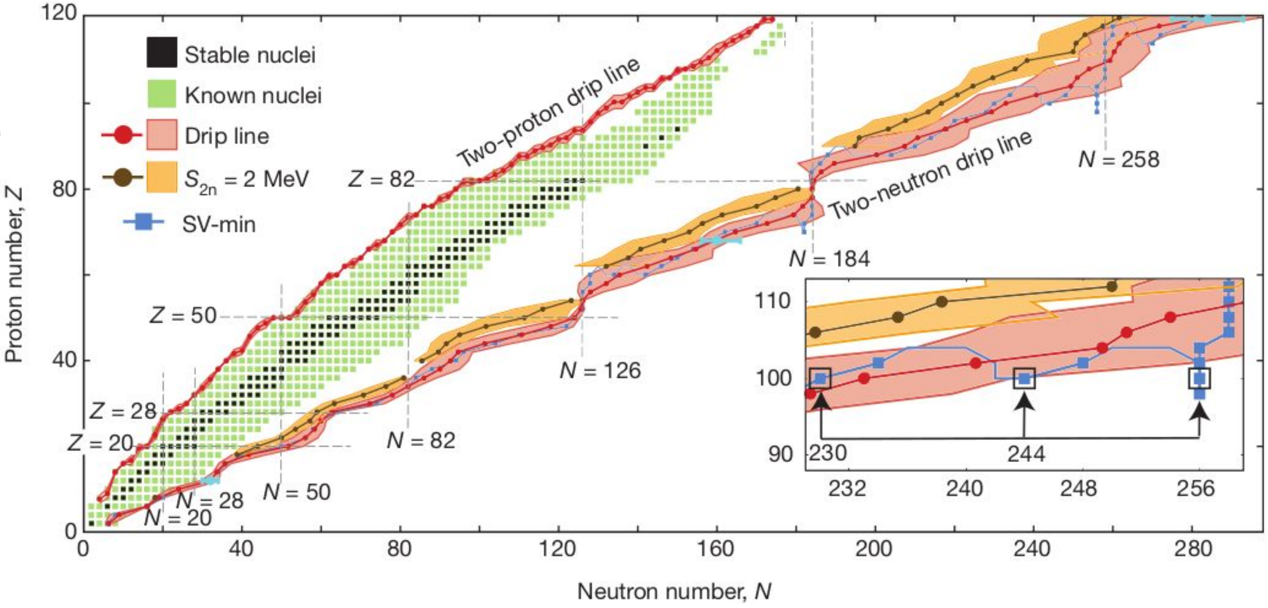
Overview

- ❖ Introduction - Physics goals
- ❖ Experimental details
- ❖ Data analysis progress
- ❖ Summary

Limits of nuclear existence

- The drip lines represent the limit of the nuclear existence.
- The proton drip line is known upto Z=91, whereas the neutron drip only upto Z=8!!

Density functional theory-
Interaction ::
-iso-scalar (binding energy, radius, charge etc) -well measured
-iso-vector (dipole polarizability, neutron skin thickness, GDR, PDR etc)- poorly constrained



Are there any first-principle calculations for nuclear interaction?

Nature 486, 509 (2012)

Ab-initio calculations - computationally challenging

Only possible for low- and medium-mass nuclei

Interactions are from Chiral Effective Field theory
- Squares - CEFT with different interactions
- Circle - CEFT with NNLO corrections

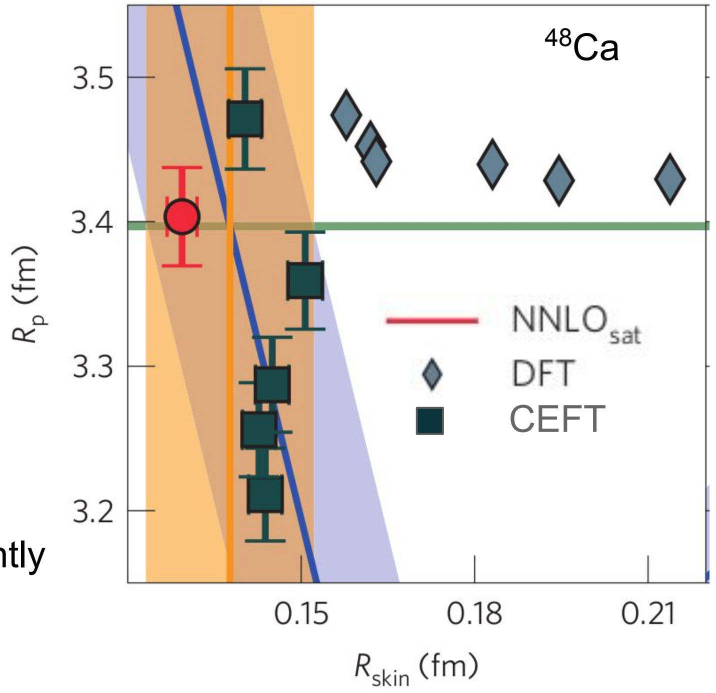
Rhombus - DFT

For ^{208}Pb - only option is the Density functional theory

Need at least a precise data point - Can be handled by both DFT and ab initio theories - ^{48}Ca is the natural choice

- ab initio calculations shows that neutron skin of ^{48}Ca is significantly smaller than that estimated by DFT!!

❖ CREX will test the ab-initio calculations!!



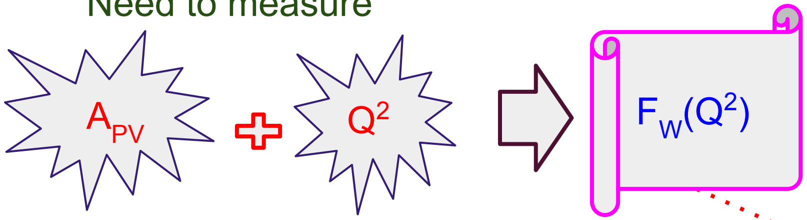
PRL 126, 172502 (2021) Nature Physics 12, 186 (2016)

CREX in Hall A at Jefferson Lab

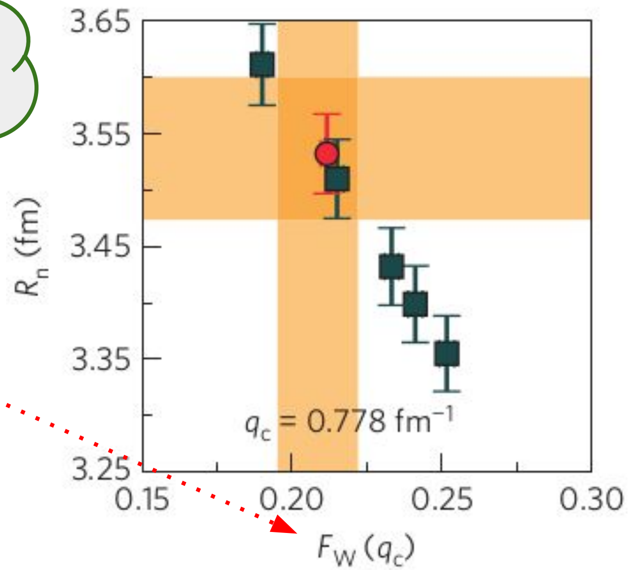
- Experimental technique: Parity-violating elastic scattering of longitudinally polarized electrons from an enrich unpolarized ^{48}Ca target

For spin 0 nuclei: $$A_{pv} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \approx -\frac{G_F Q^2 Q_w}{4\pi\alpha\sqrt{2}Z} \frac{F_w(Q^2)}{F_{ch}(Q^2)} \approx 10^{-6}$$

Need to measure



Directly compared with theory - no model!!



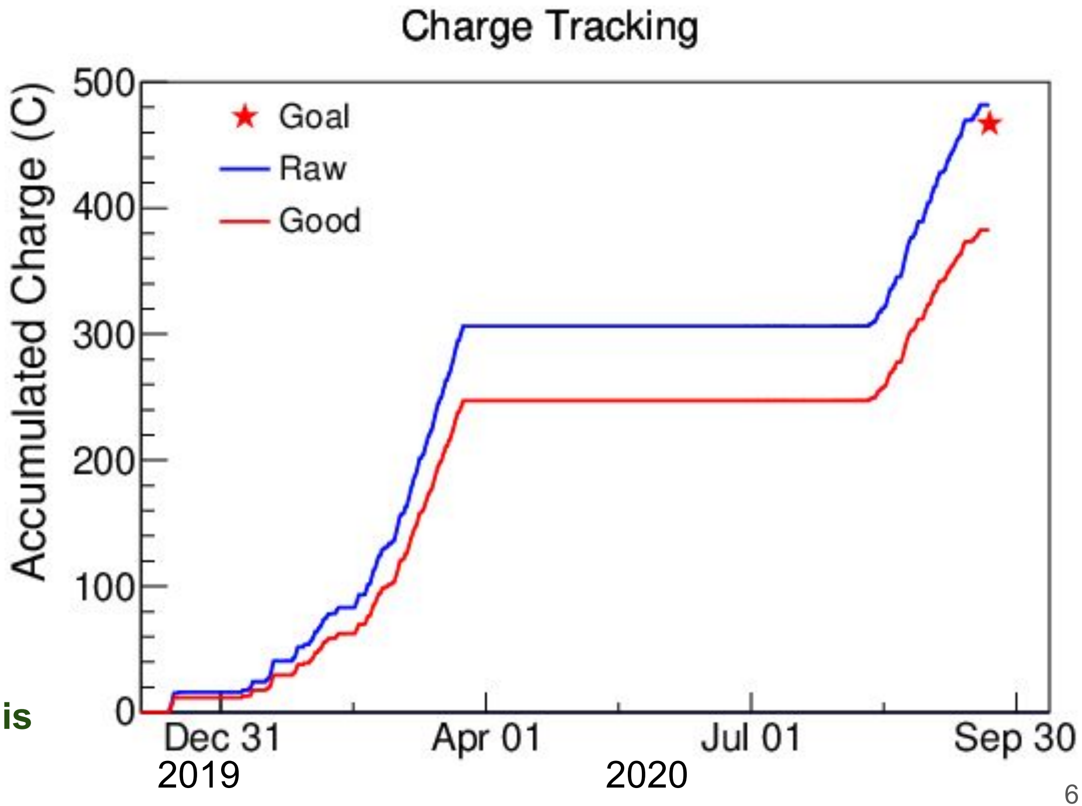
Nature Physics 12, 186 (2016)

^{48}Ca neutron skin thickness uncertainty goal (proposed) :: ±0.02 fm

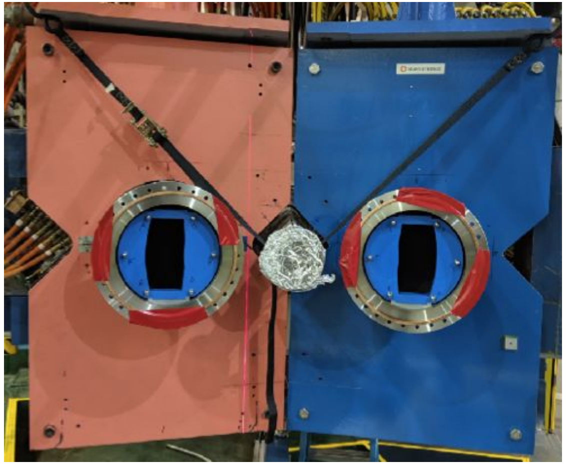
- To measure a quantity of ~ 10^{-6} with 2.4% needs very good control of systematics
- Q^2 measurement (0.8%) requires precise knowledge of scattering angle and vertex reconstruction

CREX running timeline

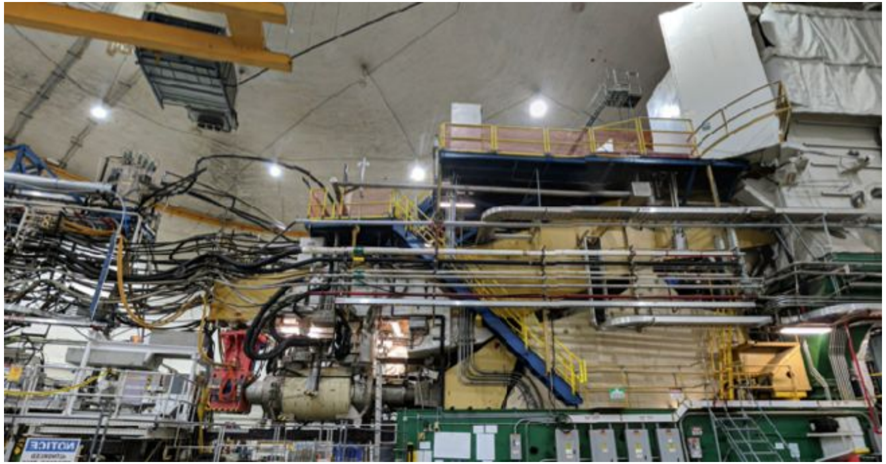
- CREX running started in the pre-covid era Dec 2019)..
- Stopped at the end of March due lab shutdown
- Started in Aug and ended mid-Sept 2020.
- Total raw charge on target = 482 C
- ‘Good’ charge 383 C (80% of our goal)



We thank all who helped to complete our data taking in the middle of the world crisis

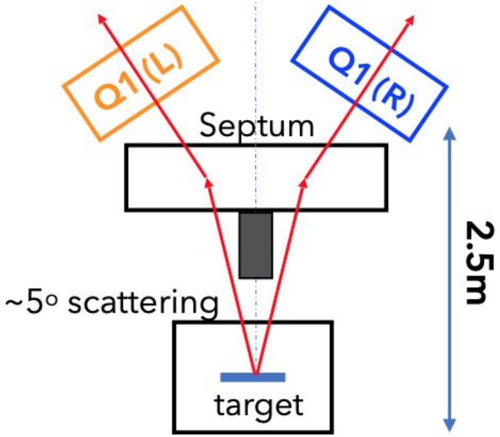


HallA Spectrometers and CREX setup

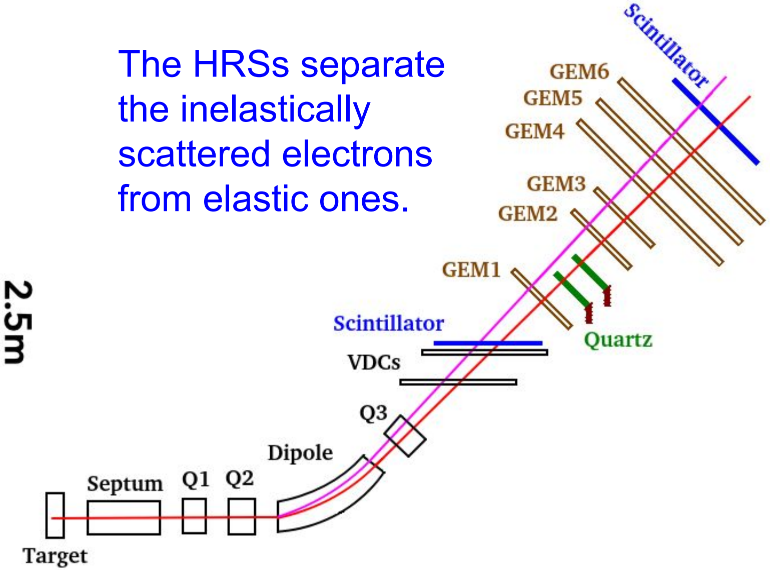


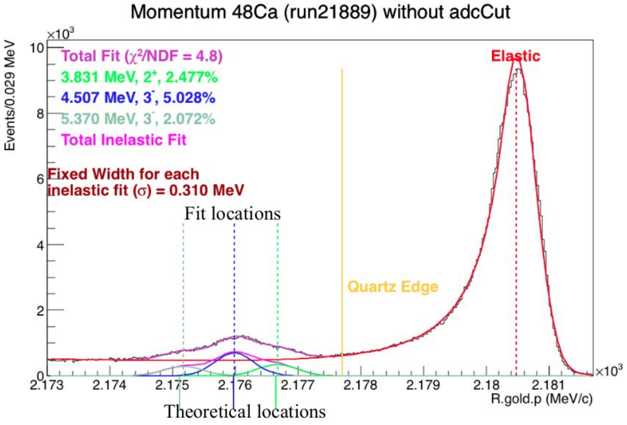
CREX kinematics
E = 2.18 GeV
I = 150 μA
Scattering angle ~ 5 deg

~12.5^0 spectrometers



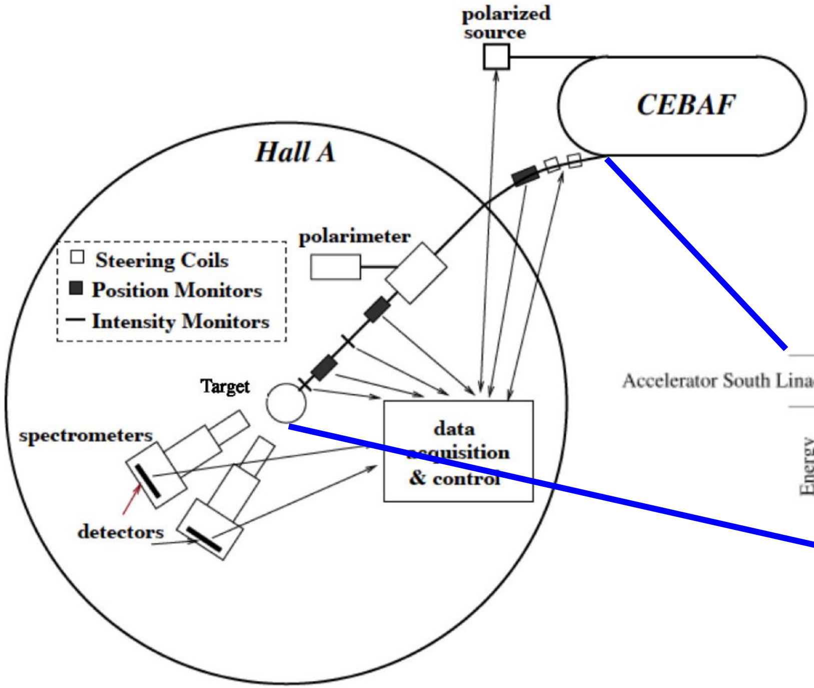
The HRSs separate the inelastically scattered electrons from elastic ones.

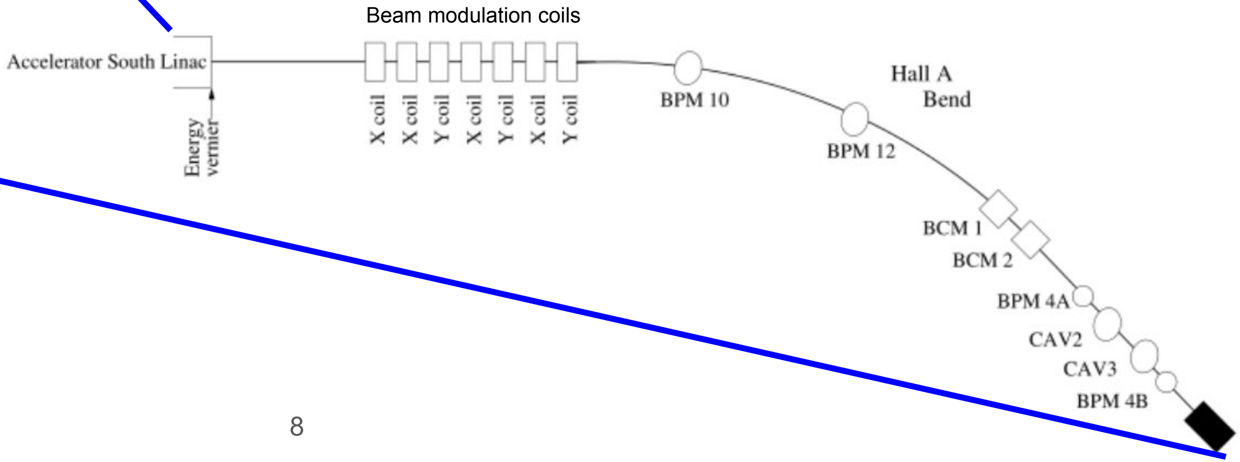




Control of the experiment

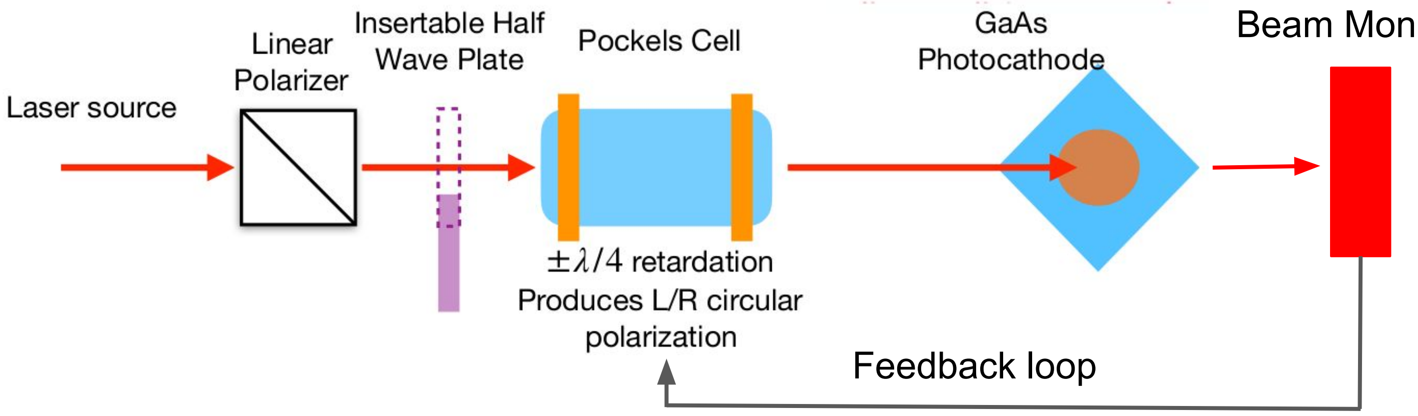
Not only detectors and beam instruments in the hall are recorded - The polarized source information was one of the crucial parts of our data stream





Polarized Source

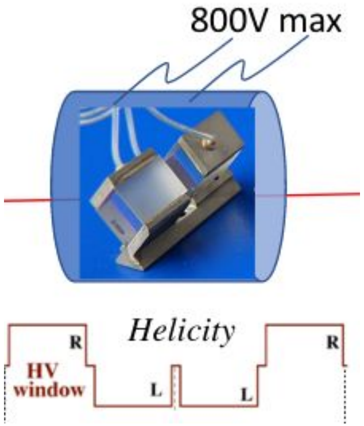
JLab provides very-low noise and well-controlled polarized beam!!

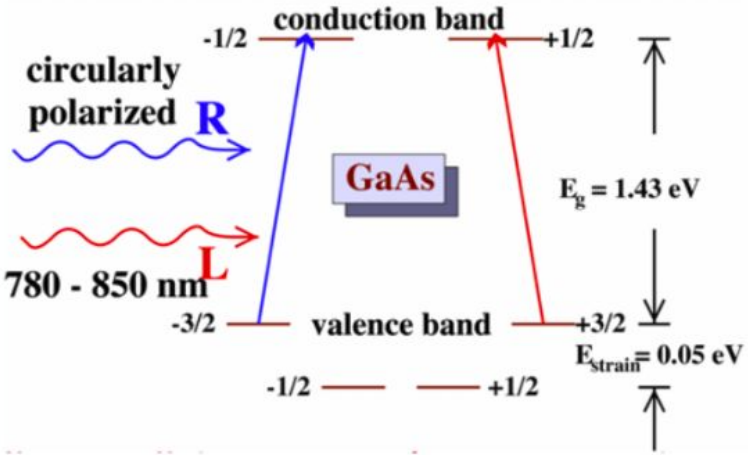


What if this monitor sees some beam asymmetry?? - Helicity correlated asymmetry

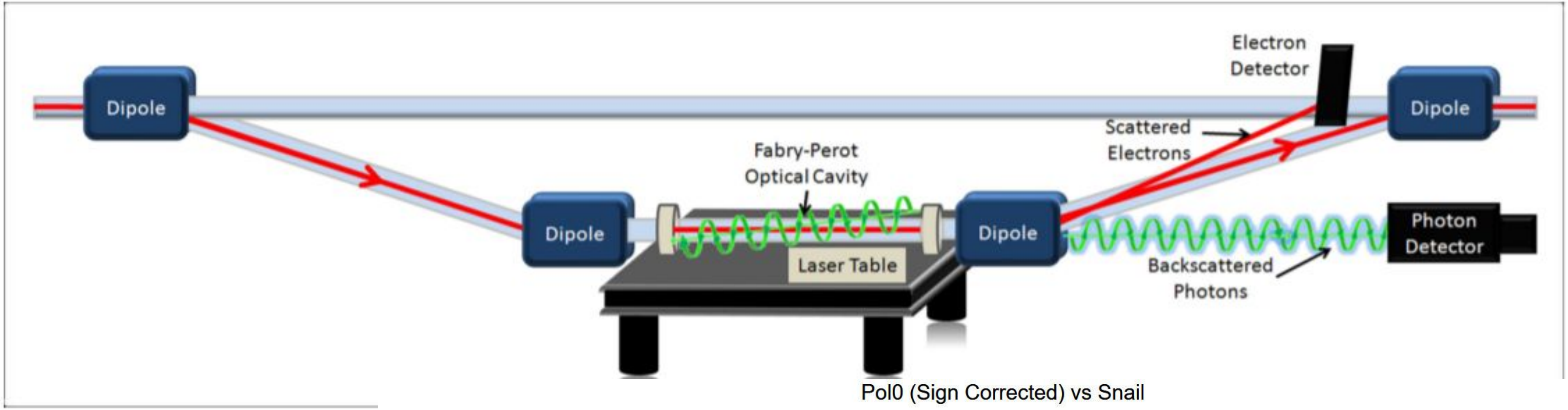
To cancel beam asymmetry-

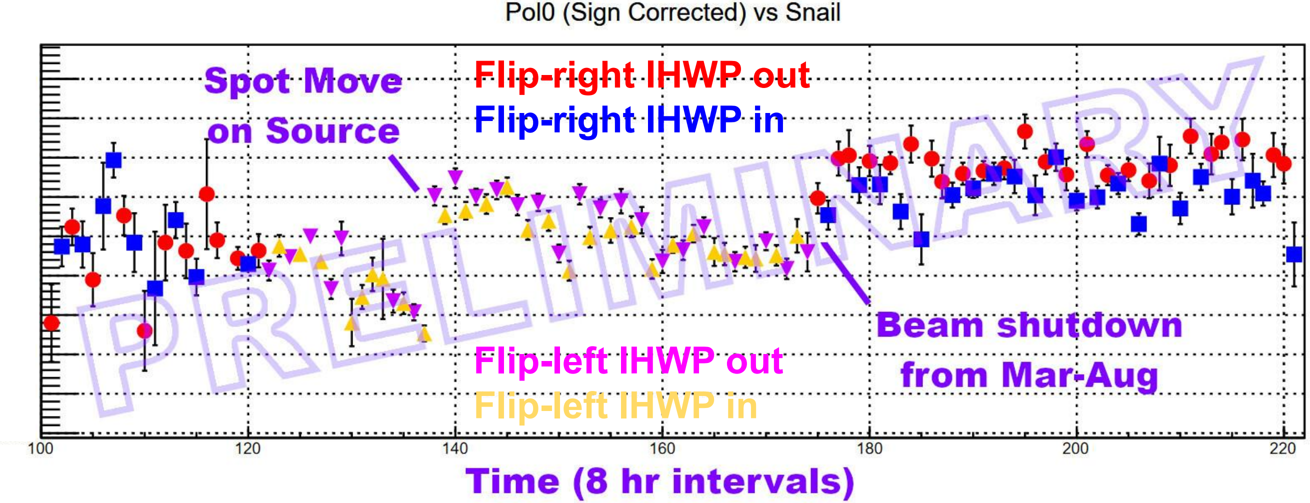
- Need rapid (120 0r 240 Hz) and controlled helicity flip - Pockels Cell
- Slow-helicity reversal (every 8 hours) - Insertable Half wave plate
- Double Wien rotation - Electromagnetically rotate electron's spin





Polarization measurements - Compton polarimeter





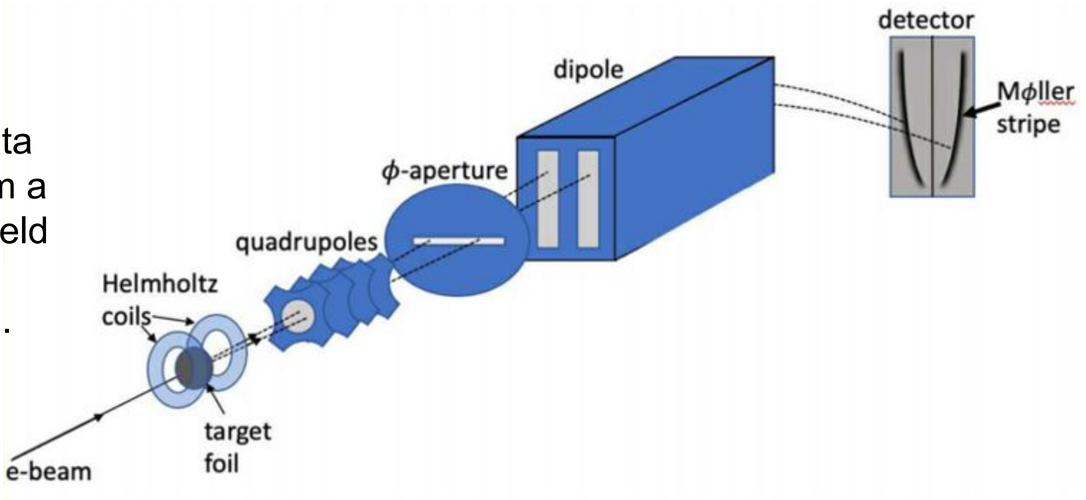
Compton Polarimeter

- Non-invasive measurement
- ~88% polarization
- Systematic uncertainty is still under review

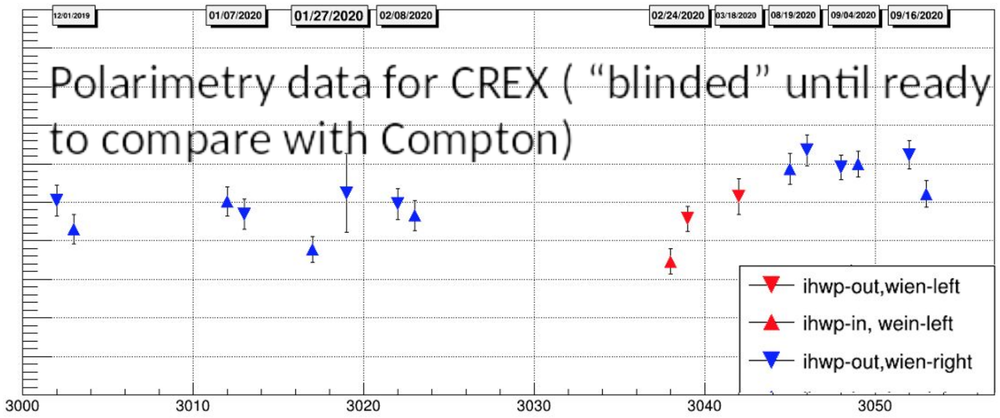
Polarization measurements - MOLLER Polarimeter

MOLLER Polarimeter

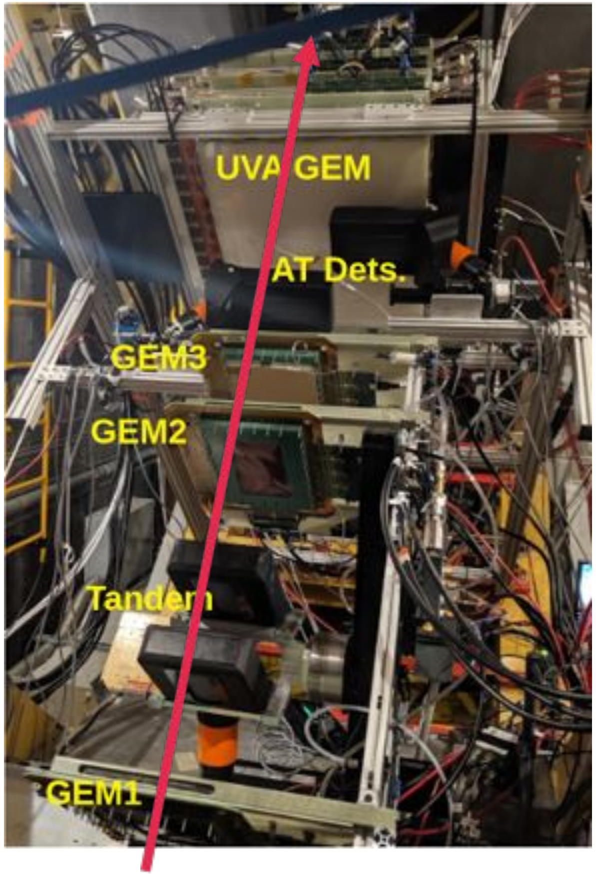
- Low current invasive measurements - Took fewer runs to cross-check with Compton data
- MOLLER -scattering of beam electrons from a magnetized Fe foil using a 3-4T magnetic field
- No significant fluctuation of measured polarization is observed over the run period.
- **Statistics: <0.25% per measurement**
- **Systematic: 0.85% relative uncertainty**



Source	Error (%)
A_{zz}	0.175
Foil polarization	0.571
Current bleedthrough	0.09
Laser polarization	0.07
High current extrapolation	0.51
Other	0.31
Total	**0.85**



Detector systems

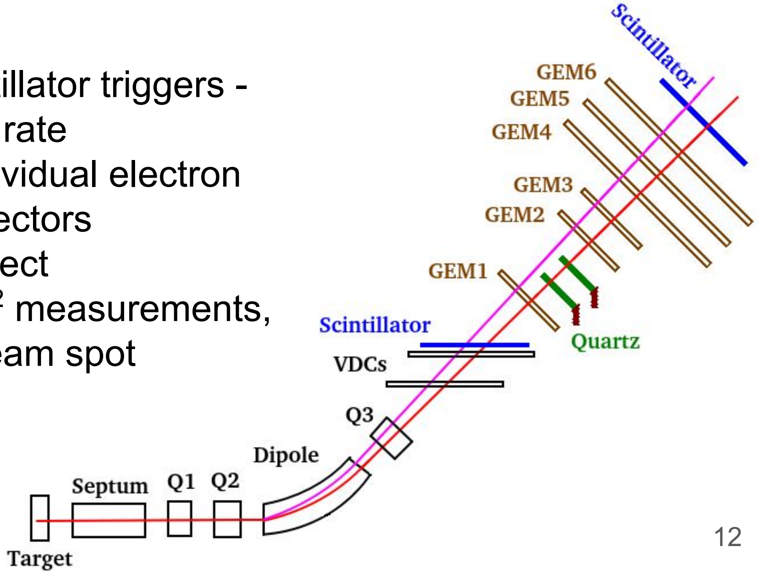


Integrating detectors:

- Charge integration method to reach statistical goal - 150 μA beam with helicity trigger - 28 MHz electrons ~ 3x3 cm^2 area
- **Radiation hard** fused silica (Two in each HRS arm) - Cherenkov detectors
- PMT non-linearity is tested on bench and with beam during the experiment

Counting detectors:

- 50 nA beam with scintillator triggers - few hundred Hz trigger rate
- VDCs, GEMs and individual electron signal in the quartz detectors
- Used to establish correct spectrometer optics, Q^2 measurements, detector alignments, beam spot checking etc.



Q^2 - measurements

$$Q^2 = 2EE'(1 - cos\theta)$$

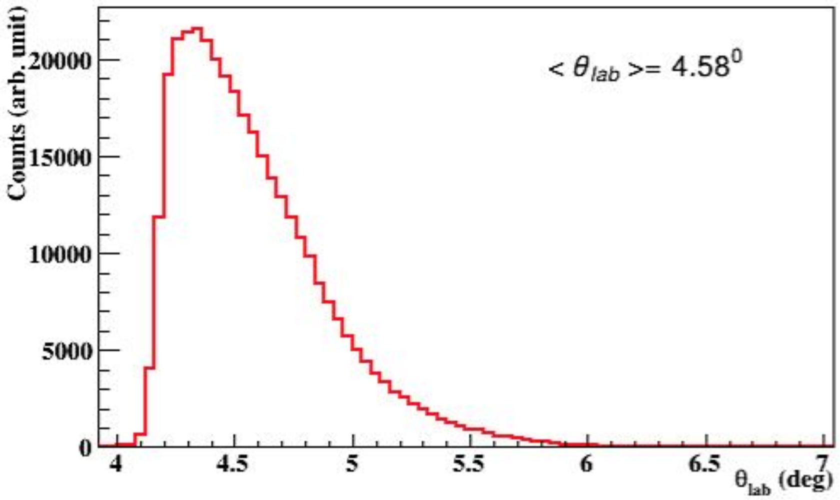
$$E, E' \equiv incident\ and\ scattered\ energy$$

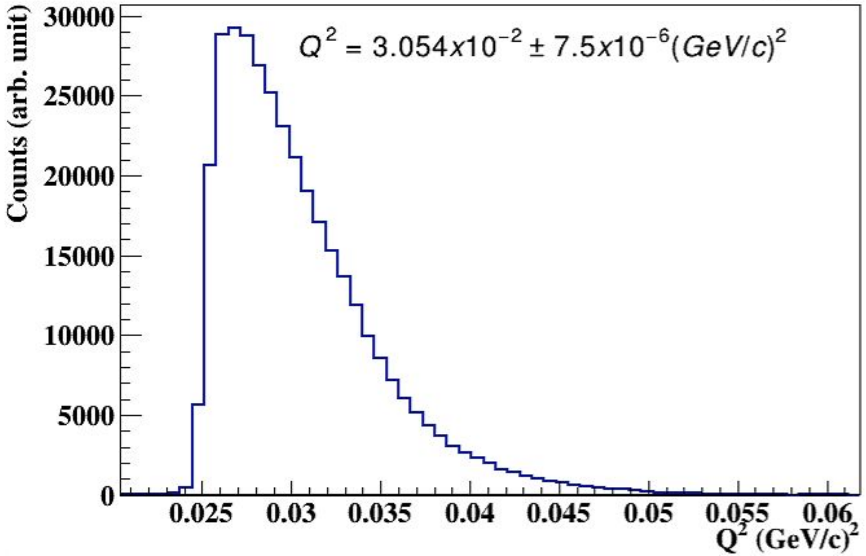
$$\theta \equiv scattering\ angle$$

CREX measured the average angle over the experimental acceptance (top right graph)

Q^2 measurements are performed periodically over the run and found to be stable

$Q^2 = 3.054(0.00075)\times10^{-2}\ (\mathrm{GeV/c})^2$
Similar Q^2 values are observed for both arms



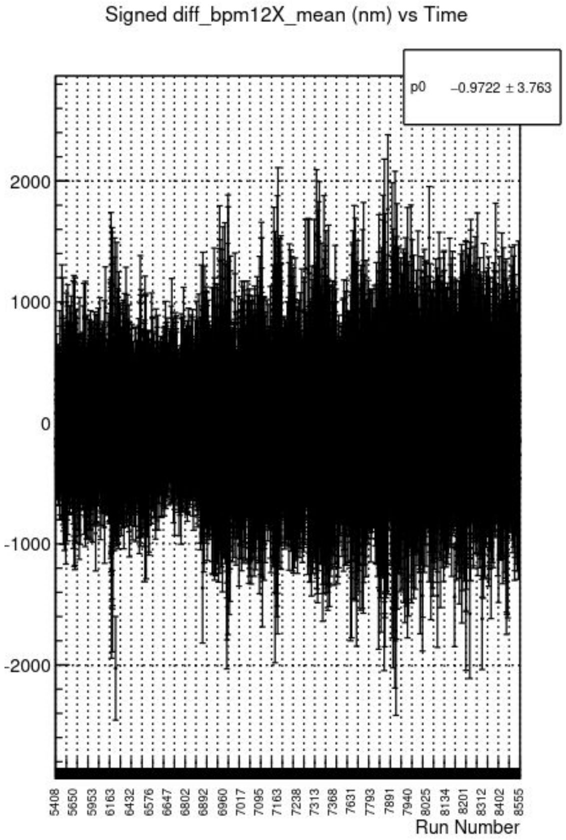


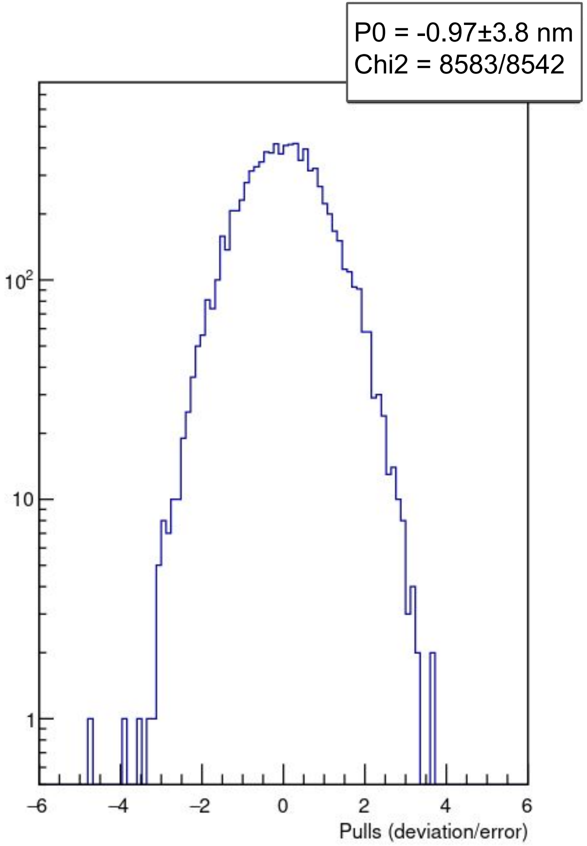
Monitored the beam motion using many BPMs

Beam moved between the two heicity periods

The difference of beam position between the two helicity windows are ~2μm

-Forced regression
-Using the beam modulation coils, forced the beam to move and calculated the sensitivity & used it for correcting the beam motion





Beam motion corrected asymmetry - **Blinded**

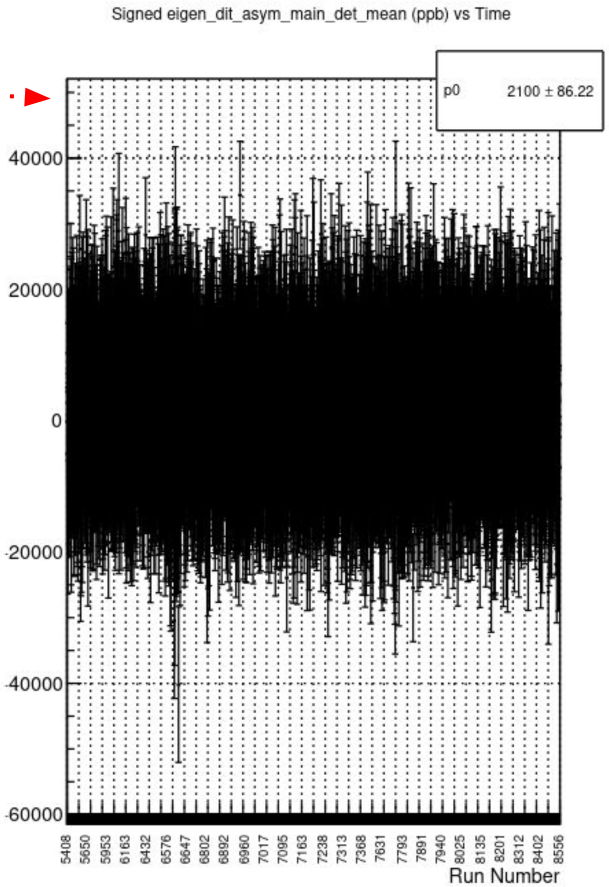
$$A = A_{raw} - A_Q - \sum_i \alpha_i \Delta x_i - \alpha_E A_E$$

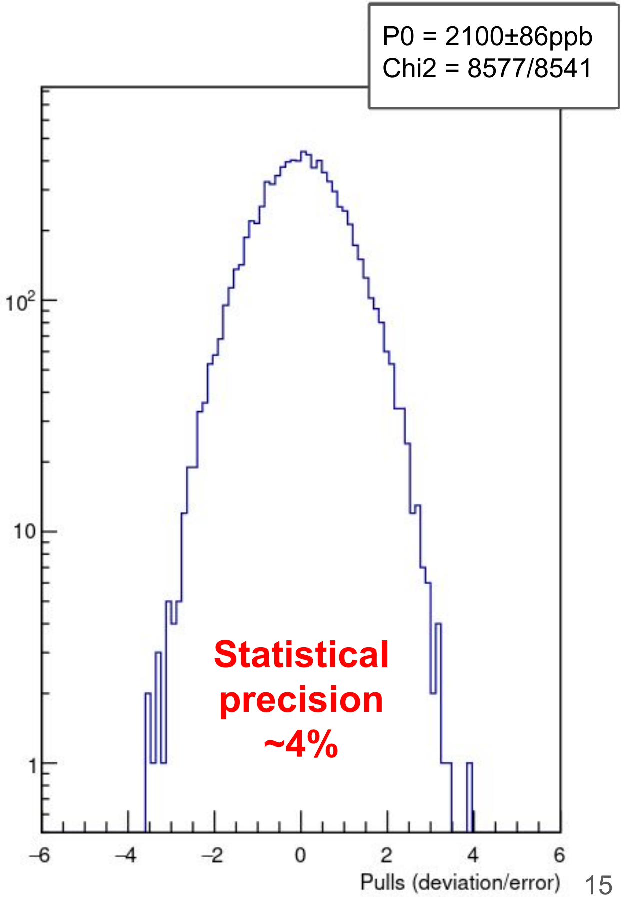
A_{raw} :: Raw asymmetry

A_Q :: Charge asymmetry

α_i :: Beam sensitivity

Δx_i :: change of beam parameter





-Needs to correct for the polarization and finite acceptance of the spectrometers - **ongoing**

-Estimate the systematics errors- **ongoing**

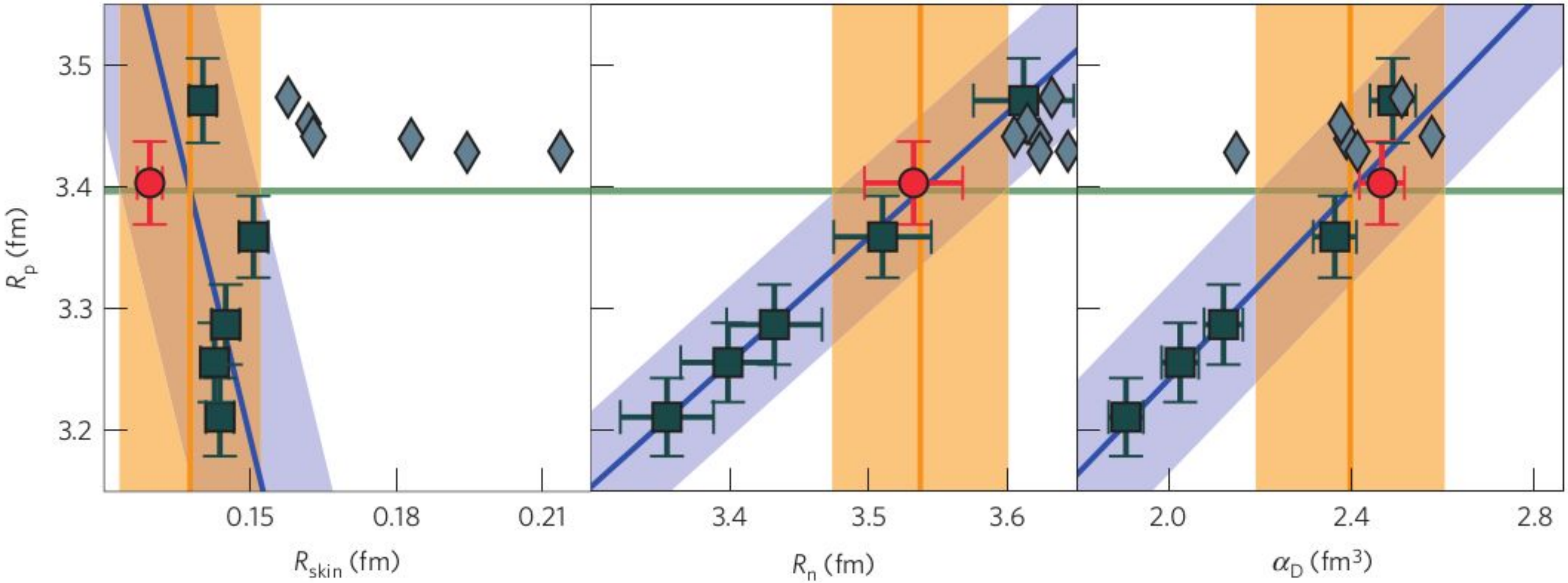
Conclusions

- The precise measurement of the weak charge of the ^{48}Ca nucleus will provide a very good test of the ab-initio calculations.
- The CREX run was very successful.
- The data analysis is progressing pretty well.
- We are expecting to release our result within few months.
- The publication will be out by end of this calendar year.

Thanks to HallA staffs, MCC crews, all shift-takers, and all of you..

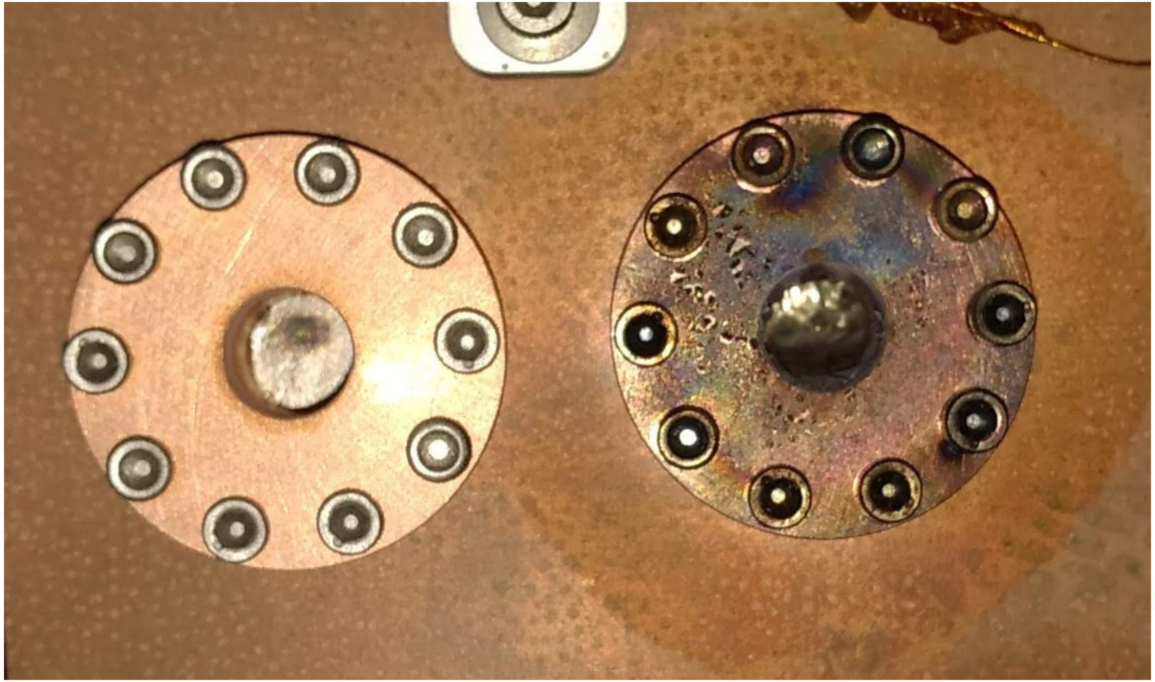
Extra Slides

Ab-initio calculations for ^{48}Ca nucleus

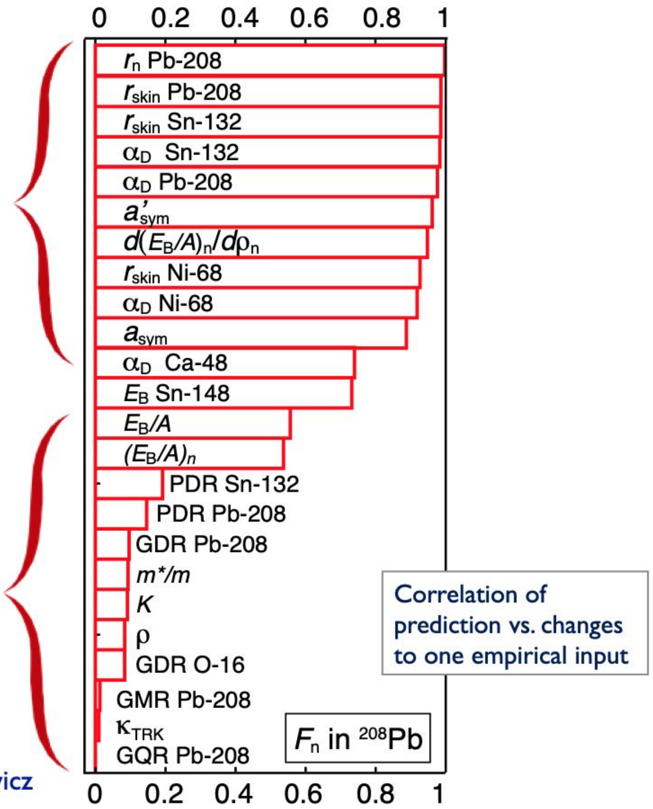


Nature Physics 12, 186 (2016)

CREX targets



Isovector constraints



Jorge Piekarewicz