PREX/CREX
Hall A collaboration Meeting

Chandan Ghosh
(on behalf of PREX/CREX collaboration)
Size of atomic nuclei

❖ Proton distribution:
  ➢ Due to electric charge - proton distribution is measured using electron scattering.

❖ Neutron distribution:
  ➢ Studied with hadron scatterings - model dependent.
  ➢ Parity-violating electron scattering gives a clean measurement of neutron distribution.

❖ For neutron rich nuclei - may exist neutron skin ($R_n - R_p$).

<table>
<thead>
<tr>
<th>Charge</th>
<th>Proton</th>
<th>Neutron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Weak</td>
<td>0.08</td>
<td>1</td>
</tr>
</tbody>
</table>

Photon sees protons, $z^0$ sees neutrons
PVES as clean probe for neutron distributions

For spin 0 nuclei:

\[ A_{PV} \approx - \frac{G_F Q^2 Q_W}{4\pi\alpha\sqrt{2}Z} \frac{F_W(Q^2)}{F_{ch}(Q^2)} \]

\[ A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim 10^{-4} \times Q^2 \sim 10^{-6} \]

Asymmetry could be used for testing models

PRL 106, 252501 (2011)
Choice of two targets - $^{208}\text{Pb}$ and $^{48}\text{Ca}$

- $^{208}\text{Pb}$ is doubly magic neutron rich nucleus - well studied both experimentally and theoretically.

- $^{48}\text{Ca}$ is also doubly magic nuclei - ab initio calculations [G. Hagen et al., Nature Physics 12, 186 (2016)] are possible.

- First excited state for these nuclei are high in energy (2.6 MeV for $^{208}\text{Pb}$ and 3.8 MeV for $^{48}\text{Ca}$).

- Theoretical correlation of $R_{np}$ can be compared with measured values.
Nuclear symmetry energy and PREX

Symmetry energy (S): Variation of binding energy as $n/p$ changes.

Slope of symmetry energy: $L \propto \frac{\delta S(\rho)}{\delta \rho} \bigg|_{\rho_0}$

$R_{np}$ is highly sensitive to pressure of pure nuclear matter: greater the $L$, larger the neutron skin thickness as the neutrons are pushed against ‘surface tension’.

B.A. Brown PRL 85, 5296 (2000)
PREX-I results

PREX-I result: $A_{PV} = 0.656 \pm 0.060 \pm 0.014$ppm  
$\Delta R_{np} = 0.33^{+0.16}_{-0.18}$fm

Phys Rev Lett. 108, 112502 (2012); (251 citations)

LIGO: Neutron star merger (2017)

- Theoretical limit on $^{208}$Pb and neutron star radius
  - same physics for two wildly different systems
- PREXII constrains the EOS of neutron rich matter. If data are inconsistent it could be a hint of possible phase transition at very high density of neutron star.

arXiv:1711.06615
F. J. Fattoyev et al.
**PREX/CवEX beam time and systematic goal**

PREX - 25+10 days, 0.06fm  
CREX - 35+10 days, 0.02fm

<table>
<thead>
<tr>
<th><strong>PREXI</strong></th>
<th><strong>PREXII</strong></th>
<th><strong>CREX</strong></th>
</tr>
</thead>
</table>
| E = 1.06 GeV, 70 uA  
$A_{pv} = 0.6$ ppm; | E = 0.95 GeV, 70 uA  
$A_{pv} = 0.6$ ppm; Rate ~ 2.2 GHz | E = 2.18 GeV, 150 uA  
$A_{pv} = 2$ ppm; Rate ~ 27 MHz |
| Charge Normalization | Charge Normalization | Charge Normalization |
| 0.2% | 0.1% | 0.1% |
| Beam Asymmetries | Beam Asymmetries | Beam Asymmetries |
| 1.1% | 1.1% | 0.3% |
| Detector nonlinearity | Detector nonlinearity | Detector nonlinearity |
| 1.2% | 0.5% | 0.3% |
| Transverse Asym | Transverse Asym | Transverse Asym |
| 0.2% | 0.2% | 0.1% |
| Polarization | Polarization | Polarization |
| 1.3% | 1.1% | 0.8% |
| Inelastic Contribution | Inelastic Contribution | Inelastic Contribution |
| <0.1% | <0.1% | 0.2% |
| Effective $Q^2$ | Effective $Q^2$ | Effective $Q^2$ |
| 0.5% | 0.4% | 0.8% |
| Total | Total | Total |
| 2.1% | 2% | 1.2% |

PREXI - Goal achieved - Systematic was under control, limited by statistics
PREX running and radiation

- Started -17 June 2019; Ends - 18 Aug 2019 (scheduled)
- Lost some time due to leakage in the water cell target and sitewide power outage.
- Extension - 3 weeks (Ends -9 Sept) - Thanks to Lab management.
- We were very good in terms of radiation inside hall and boundary detector.

Upto 5th August 2019, we reached 6% of year’s radiation budget!!

https://logbooks.jlab.org/entry/3715102
Radiation Shielding

CAD drawing near target region
Detectors

PREX Optics Schematic

Projected x on detector plane

$^{48}\text{Ca}$

Elastic

Inelastic

Mean = -0.048

Transverse Asymmetry detector

SBS GEM dets

GEM

D. McNulty
PREXII beam quality

 Slug - change of half-wave plate or wien flip

 Charge asymmetry

\[ Asym = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \]
PREXII charge

- Goal of accumulated charge: 150 C
- Good charge accumulated: 118.24 C (~79%)

End of run target condition
PREXII Data Set

Blinded Asymmetry

Collaboration is working actively on analysis

\[ Q^2 = 0.0063 \, (GeV/c)^2 \]
PREXII Polarization measurements

Fe 10 micron, Aug. 31th 2019, HWP out, slit 50%, 4 T, 0.4 muA

\[ \chi^2 / \text{ndf} = 13.72 / 14 \]

Prob = 0.4706

p0 = 0.8991 ± 0.003279

Preliminary
CREX running

- Started: 5 Dec 2019 - 17 Dec 2019; 6 Jan 2020 - still going (47% of scheduled time)

- We had a target accident on Jan 18.
- Thanks to target and radiation group to replace the target quickly and bring us back to production
CREX beam quality

\[ Asym = \frac{\sigma^+-\sigma^-}{\sigma^+ + \sigma^-} \]
CREX results - online analysis plots

Clean data - no non-gaussian tail

\[ \sigma = 1080 \text{ ppm} \]

\[ Q^2 = 0.030 (GeV/C)^2 \]

<table>
<thead>
<tr>
<th>hQsq</th>
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<tbody>
<tr>
<td>Entries</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Std Dev</td>
</tr>
</tbody>
</table>
CREX Polarization measurements

So far we don’t have beam polarization measurement using Compton setup

https://logbooks.jlab.org/entry/3772271
Where are we in CREX running??

- Goal: 450 C; Good charge accumulated: 39 C (~9%)!!

We have to go a long way - please join..
Summary

-PREX/CREX - fundamental nuclear physics with many applications. Results are highly anticipated by abroad community.

-PREXII went well. We are working on analysis - aiming results in fall 2020.

-CREX is running - long way to go...