PREX and CREX Update
Measuring the Neutron Radii of ^{208}Pb & ^{48}Ca

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Hall A Collaboration Meeting

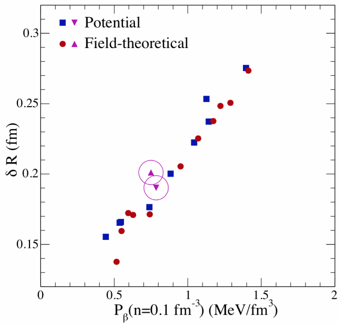
9 December, 2014

Physics Motivation - Neutron Densities

- Proton and neutron densities are both important in our quest to understand nuclear matter.
- Proton densities are easy to obtain from electromagnetic probing.
- Neutron densities are a bit harder to obtain.
- *Why do neutron densities interest us?*

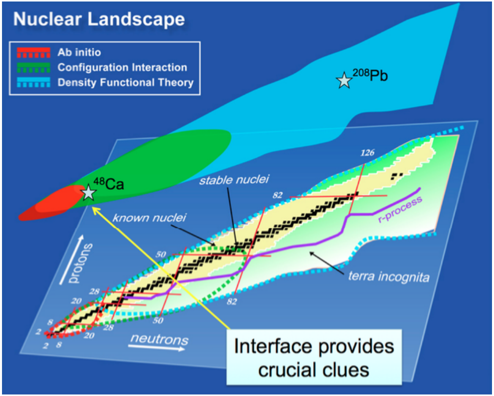
Physics Motivation - Neutron Stars, Symmetry Energy

- A measurement of R_N, the rms radius of the neutron distribution, provides constraints on equations of state for neutron rich matter.
- There exists a strong correlation between the neutron skin $\delta R = R_N - R_P$ and the pressure P in neutron stars.
- Correlation between R_N and the radius of a neutron star.
- The EOS of neutron rich matter is closely related to the symmetry energy.
- Symmetry energy is the difference in energy per nucleon between neutron rich and symmetric nuclear matter.



A. Steiner, M. Prakash, J. Lattimer, P. Ellis, Acta Phys.Hung. A25 (2006) 203-210

Physics Motivation - Why ^{208}Pb & ^{48}Ca?



- We need a neutron excess.
- We need a large inelastic state separation.
- We need long lifetimes for stability.
- We need two nuclei whose masses are far apart.

Parity Violating Electron Scattering

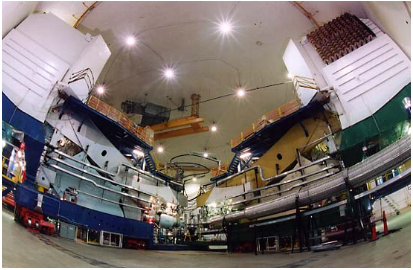
- We can perform electron scattering off of ^{48}Ca and ^{208}Pb.
- Taking the parity violating asymmetry allows us to become sensitive to the neutron distribution through Z^0 exchange.

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[1 - 4\sin^2(\theta_W) - \frac{F_N(Q^2)}{F_P(Q^2)}\right] \tag{1}$$

- A_{PV} gives us access to $F_N(Q^2)$.
- $F_N(Q^2)$ gives us access to R_N.

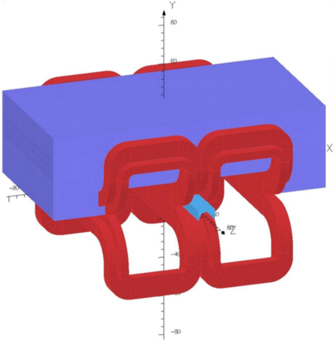
Experimental Setup - Hall A Apparatus

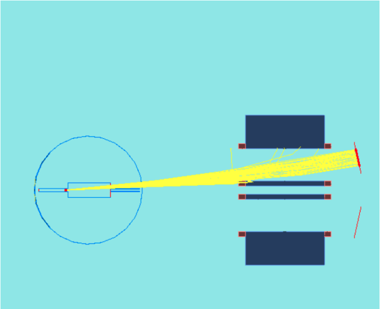
- PREX/CREX makes use of HRSs in Hall A.
- PREX needs to accept events at 5°, and E = 1.06 GeV.
- CREX needs to accept events at 4°, and E = 2.2 GeV.
- For PREX we anticipate an asymmetry of 0.6 ppm $\pm$ 0.02 ppm.
- For CREX we anticipate an asymmetry of 2 ppm $\pm$ 0.048 ppm.



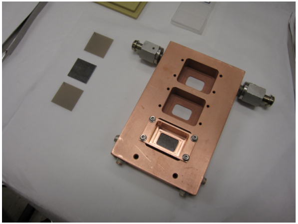
Experimental Setup - Septum

- In order to accept events at such small angles, we use septum magnets to bend our events of interest from $4^\circ/5^\circ$ to the forward-most 12.5° of the HRSs.



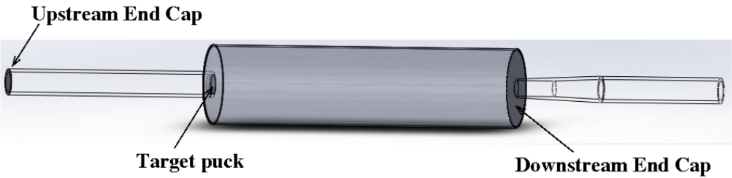


Experimental Setup - PREX Target



- Lead/Diamond Targets
- 0.5 mm Pb wafer, 9% radiator
- 0.25 mm diamond wafer
- Cryogenically cooled frame, 4 mm $\times$ 4 mm raster
- PREX I: Pb damaged at high current - using thicker diamond

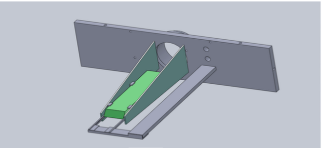
Experimental Setup - CREX Target

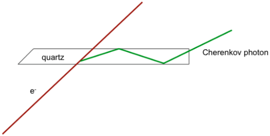


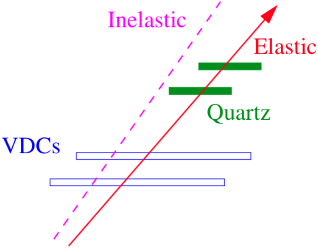
- 5% radiator
- ^{48}Ca oxidizes when exposed to air. Must be isolated!
- 0.3 mm stainless steel walls to minimize background and isolate ^{48}Ca.

Experimental Setup - Quartz Detector

- Quartz Cherenkov detectors will be used.
- We will integrate PMT signal over helicity windows
- CREX will need a slightly longer design

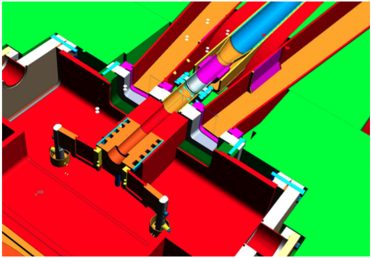






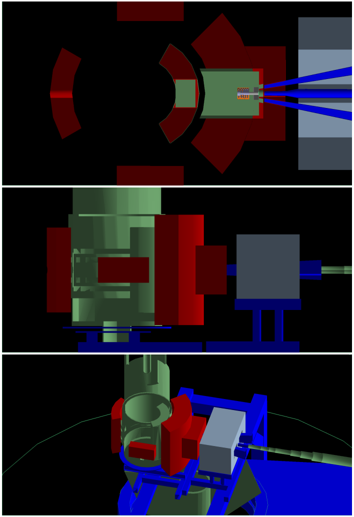
Tasks Completed - Vacuum system conceptual design

- No longer have elastomer O-rings at small scattering angles
- Now we have metal gasket seals for the beamline and acceptance apertures
- This was a previous problem from PREX I that needed to be remedied
- The failure of the previous O-rings was due to radiation and damage from thermal cycling

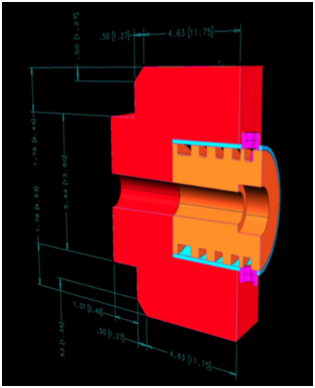


Tasks Completed - Radiation Management

- Radiation management was an issue in PREX I
- Our aim is to decrease radiation dose to hall by an order of magnitude in PREX II and CREX.
- Since last meeting, we have further optimized the shielding.
- Polythene shielding is optimized to minimize neutron flux in energies $0.1 < E < 10$ MeV.



Tasks Completed - Radiation Management



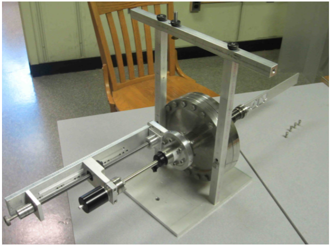
- Cu - W collimator with circulating water tank.
- Allows for a huge reduction in plastic shielding outside.

Tasks in Progress

- Upgrading Moller Polarimeter
- Optics and Q^2 calibration target choices
- Compton polarimeter

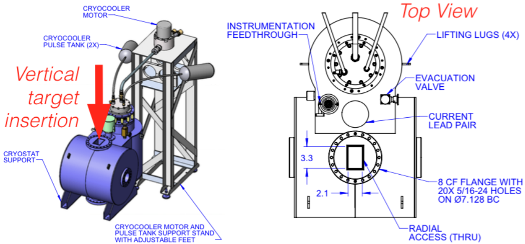
Tasks in Progress - Moller Polarimeter Upgrade

- We need a precise measurement of the polarization of the electron beam for our asymmetry measurement.
- The polarimetry group is aiming to obtain a relative precision of 0.5%.
- The group also is striving to maintain uncertainties of less than 0.1%.
- Incremental upgrades are helping us get down to 0.5% from 1.1%.
- The biggest changes up to date are the development of a new target stand, and a new 5T superconducting magnet.



Tasks in Progress - Moller Polarimeter Upgrade

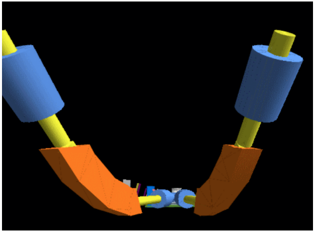
5T System purchased from American Magnetics by JLab

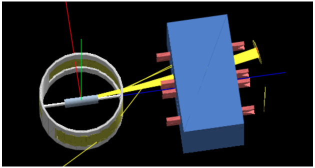


Systematic Effect	Hall C	Hall A Tilted	Hall A **Proposed**	Strategic Approach
Target polarization	0.25%	1.50%	**0.25%**	Demonstrate saturation vs **B** ...
Target angle	$\star$	0.50%	$\star$	... and tilt angle
Analyzing power	0.24%	0.30%	**0.20%**	Accurate spectrometer simulation
Levchuk effect	0.30%	0.20%	**0.20%**	Simulation w/atomic modeling
Target heating	0.05%	‡	**0.05%**	Match data to heating calculation
Dead time	‡	0.30%	**0.10%**	Confirm "zero dead time" w/FADC
Background	‡	0.30%	**0.10%**	Measurements with beam
Others	0.10%	0.50%	**0.10%**	*See text*
Total	0.47%	1.8%	**0.42%**	

Tasks in Progress - Optics, Q^2 Calibration

- Modifying Jixie's G4MC (HRSMC) for our optics studies
- We would like to make a Q^2 calibration
- We want to take a Pointing measurement instead of a survey measurement.
- Pointing measures HRS angle by looking at the energy difference of scattered electrons off of different nuclei.
- Preparing to repeat a water cell run for Q^2 calibration
- We are eyeing other candidates for backup Q^2 measurements.
- Prime candidates are dual gas cell and an ammonia puck.
- We have calculated our rates for various configurations.





Tasks to Do

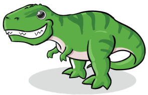
- Need to revive the following systems which worked well in PREX I.
- Beam modulation software
- Slow control and analysis software
- Integrating DAQ in injector and counting house
- Moller and Compton polarimetry.
- Septum selection for CREX

Summary

- These are challenging measurements!
- Parity violating electron scattering is the best tool to measure these neutron distributions.
- PREX and CREX will measure the neutron skin up to an precision of 0.06 fm (1%) and 0.02 fm (0.6%), respectively.
- PREX I showed high precision and systematic accuracy sufficient for ultimate goal.
- The three main issues that plagued us in PREX I are now mitigated: Radiation dose to hall, damaged targets, loss of vacuum due to failed O-rings.
- Our progress is being made, step by step, and we are on track and ramping up to run in FY16.

PREX/CREX Meeting coming up on 15-16 December!
Come check it out!

The PREX/CREX Team



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Caryn Palatchi
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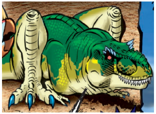
The PREX/CREX Team - Thank You!



M. Aghasyan, Z. Ahmed, K. Allada, D. Androic, K. A. Aniol, T. Averett, D. Armstrong, S. Ban, R. Barion, M. Battaglieri, E. Bellini, R. Beminiwattha, J. Benesch, J. Birchall, A. Blomberg, A. Camsonne, M. Capogni, G. Cates, A. Celentano, J .P. Chen, E. Cisbani, G. Ciullo, M. Contalbrigo, J .C. Cornejo,P. F. Dalpiaz, M. Dalton, A. D'Angelo, W. Deconinck, P. Decowski, R. De Leo, E. De Sanctis, R. De Vita, A. Deur, A. del Dotto, J. F. Dowd, L. El Fassi, GT. Forest, . B. Franklin, S. Frullani, C. Gal, F. Garibaldi, M. Gericke, R. Gilman, A. Giusa, O. Glamazdin, J. Gomez, V. Gray, P. Gueye, O. Hansen, D. Hasch, D. Higinbotham, N. A. N. Hirlinger Saylor, R. Holmes, T. Holmstrom, C.J. Horowitz, C. E. Hyde, Chun-Min Jen, S. Johnston, D. Keller, C. E. Keppel, M. Khandaker, P. Khetarpal, P. King, E. Korkmaz, S. Kowalski, K. Kumar, T. Kutz, L. Lagamba, P. Lenisa, J. LeRose, V. Lucherini, J Magee, R. Mahurin, J. Mammei, F. Mammoliti, D. J. Margaziotis, P. Markowitz, D. McNulty, F. Meddi, L. Mercado, E.-E. Meziani, R. Michaels, M. Mihovilovic, M. Mirazita, B. Moffit, S. Nanda, M. Osipenko, S. Page, C. Palatchi, L. L. Pappalardo, K. Paschke, S. A. Pereia, R. Perrino, S. K. Phillips, M. Pitt, R. Pomatsalyuk, B. Quinn, J. F. Rajotte, A. Rakhman, S. Riordan, M. Ripani, J. Roche, P. Rossi, G. Russo, B. K. Saenboonruang, Sawatzky, C. Schaerf, M Shabestari, R. Silwal, S. Sirca, P. Solvignon-Slifer, P. A. Souder, N. Sparveris, L. Sperduto, V. Sulkosky, C. Sutera, M. Taiuti, G. M. Urciuoli, W. T. H. van Oers, B. Waidyawansa, D. Wang, D. Watts, J. Wexler, R. Wilson, B. Wojtsekhowski, L. Zana, P. Zang, Z. Zhao, J. Zhang, X. Zheng, I. Zonta

Charge Normalization	0.1%
Beam Asymmetries	1.1%
Detector Non-linearity	1.0%
Transverse	0.2%
Polarization	1.1%
Inelastic Contribution	$< 0.1\%$
Effective Q^2	0.4%
Total	2%

Charge Normalization	0.1%
Beam Asymmetries	0.3%
Detector Non-linearity	0.3%
Transverse	0.1%
Polarization	0.8%
Inelastic Contribution	0.2%
Effective Q^2	0.8%
Total	1.2%

Beyond Saturation

What else is needed for precision 0.5% or better?

- Must understand spectrometer acceptance, including potential magnetic field uncertainties, to this precision.
  - *This is underway, more slides to follow*
- Magnet mapping critical, including beam line survey and possible effects of nearby yoke steel
- Levchuk effect: Need simulations with our geometry
- Radiative corrections: Simulations (see Duke group)
- Target heating and possible depolarization studies
- Electronics and DAQ dead time (should be small)
- Scattering background determination