PREX and CREX
Measuring the Neutron Skins of ^{208}Pb and ^{48}Ca

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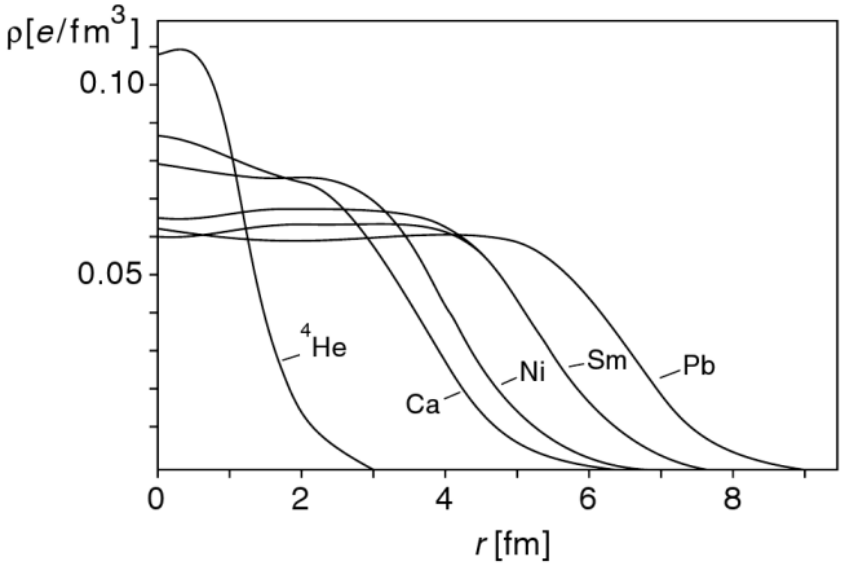
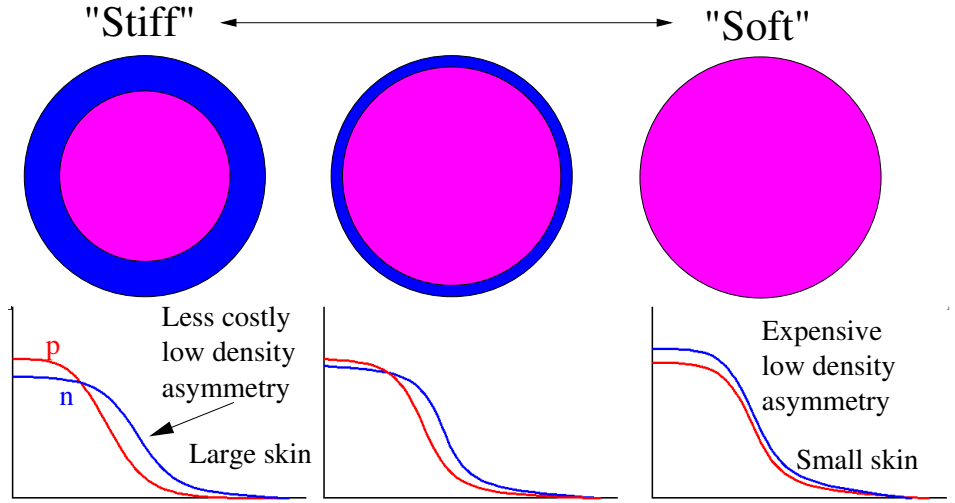
Neutron Skins and Density Dependence



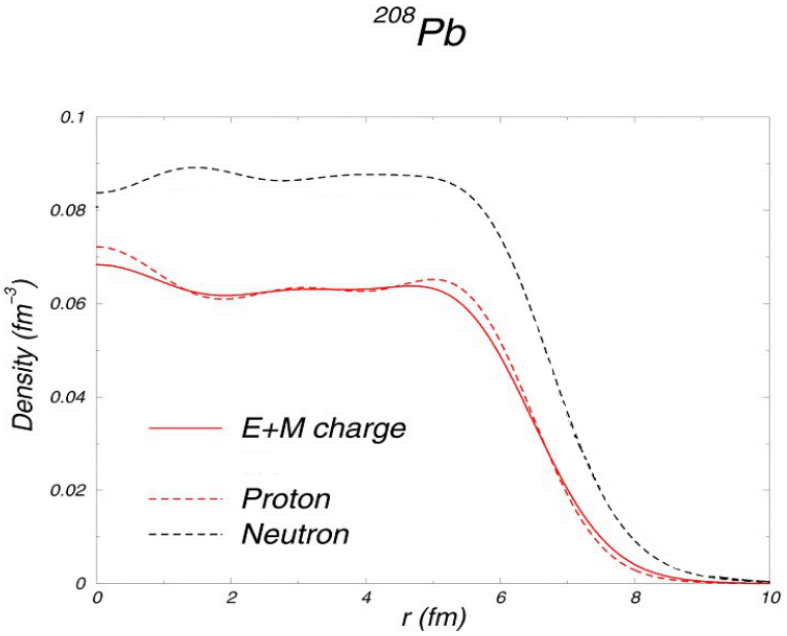
- Symmetry energy 10% of E_b for heavy nuclei
- Nuclear surfaces aren't sharp - lower density at larger radii
- Size depends on competing terms: Surface energy, Coulomb repulsion, density dependence of symmetry energy

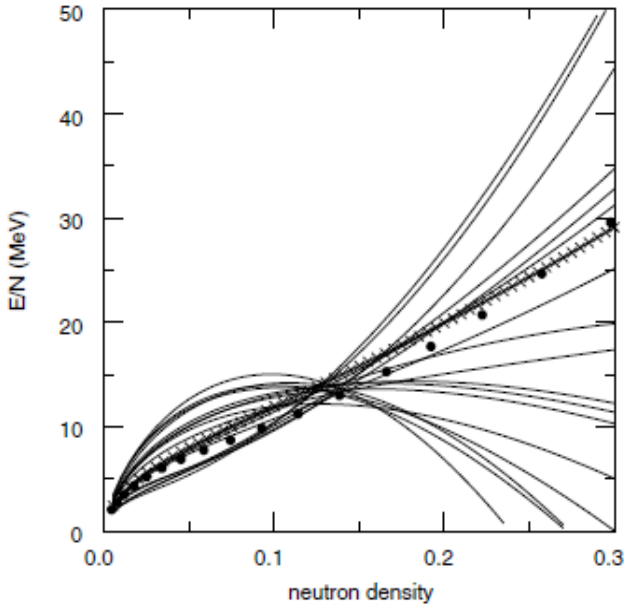


$$R_{\rm skin} \equiv$$

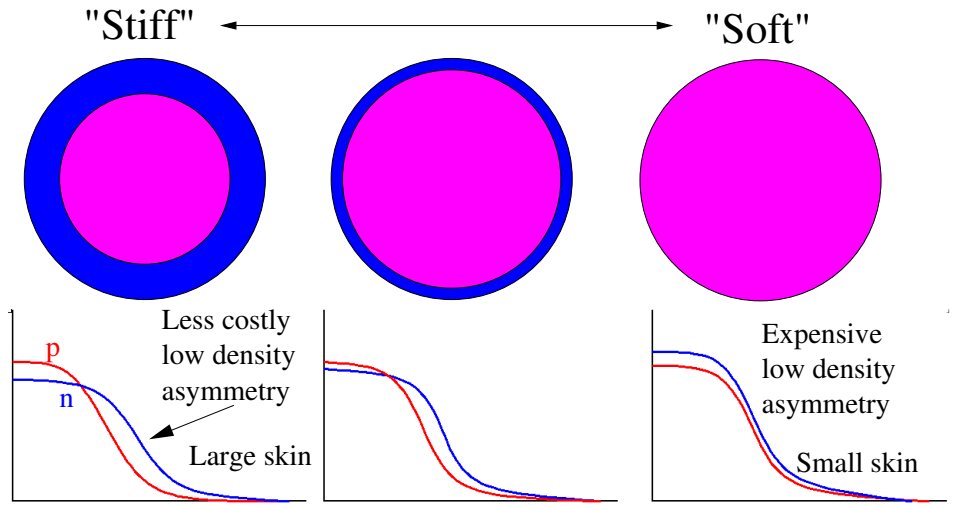
$$\sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle}$$

Neutron Skins and Density Dependence



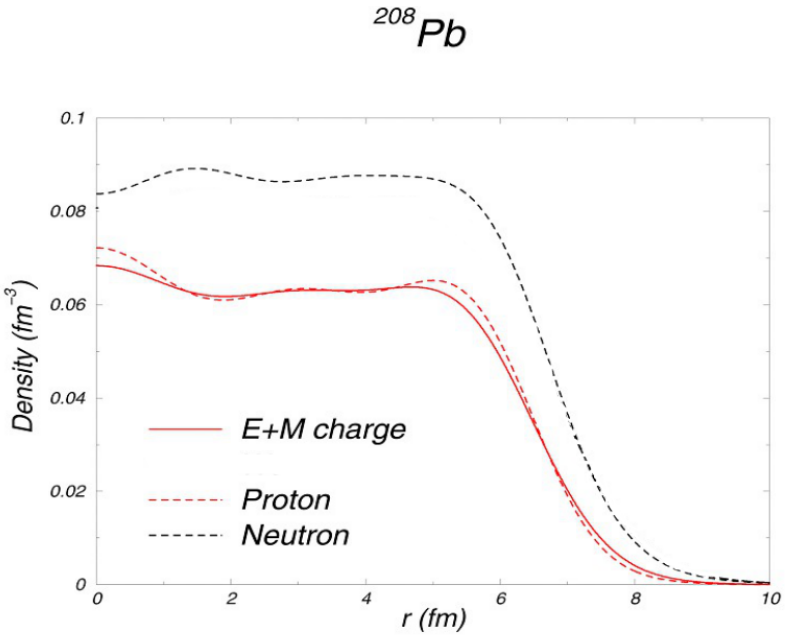


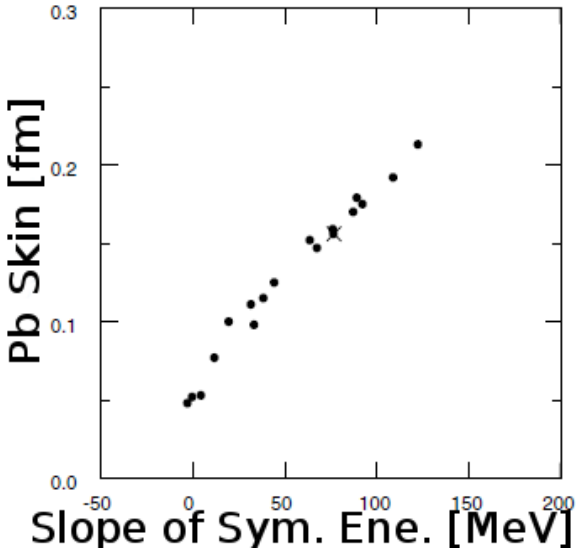
B. Alex Brown, PRL 85, 5296 (2000)



$$R_{\text{skin}} \equiv \sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle}$$

Neutron Skins and Density Dependence





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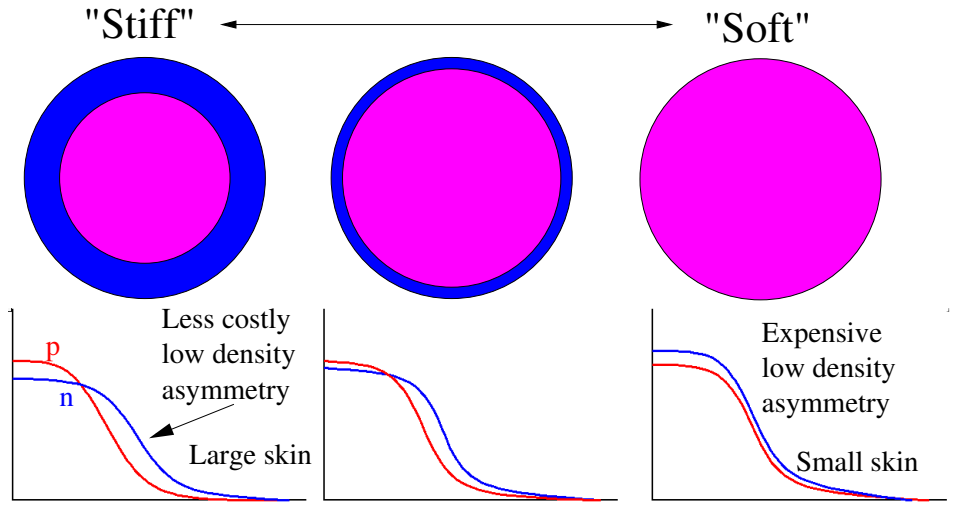
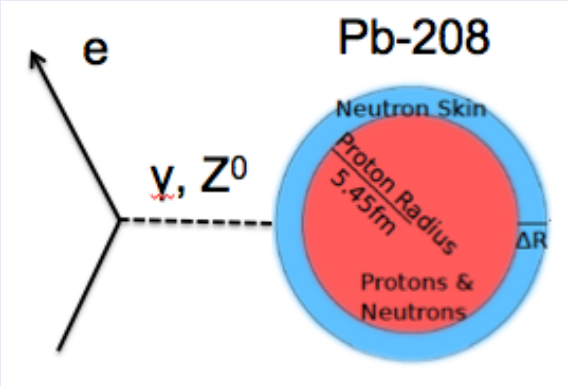


$$R_{\rm skin} \equiv \sqrt{\langle r_n^2 \rangle} - \sqrt{\langle r_p^2 \rangle}$$

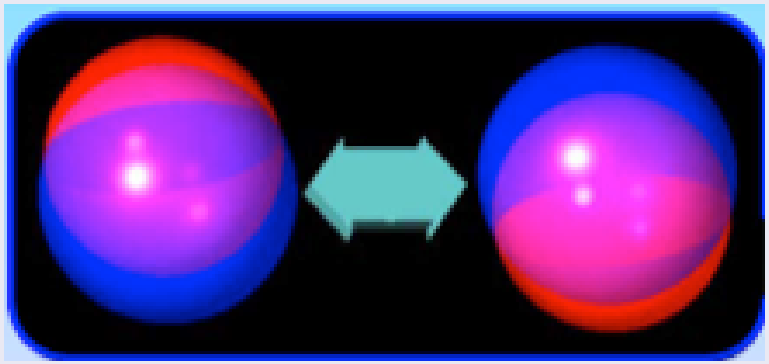
Where else does this come into play?

Lots of nuclear phenomena depend on this information!

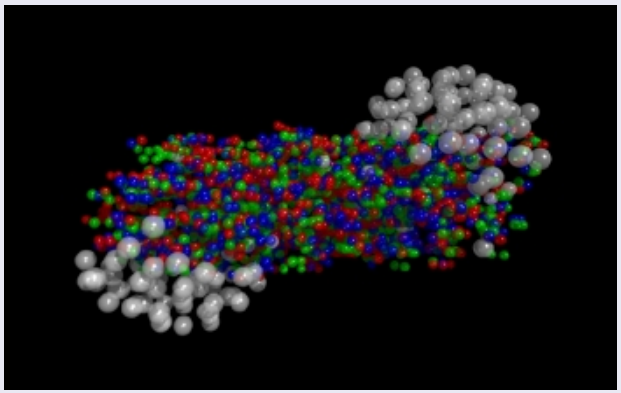
Neutron Skins



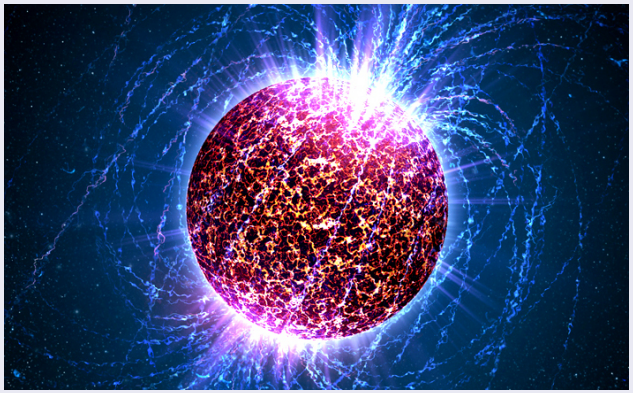
Dipole Polarizability



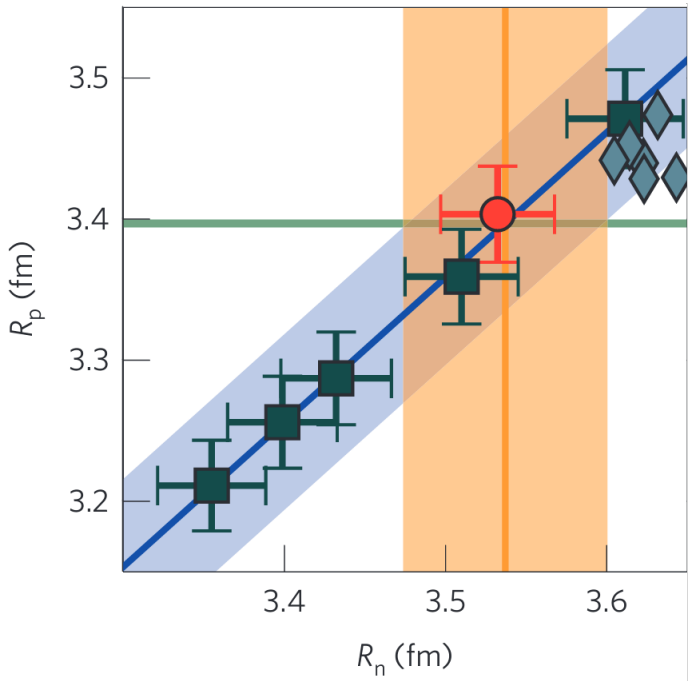
Heavy Ion Collisions



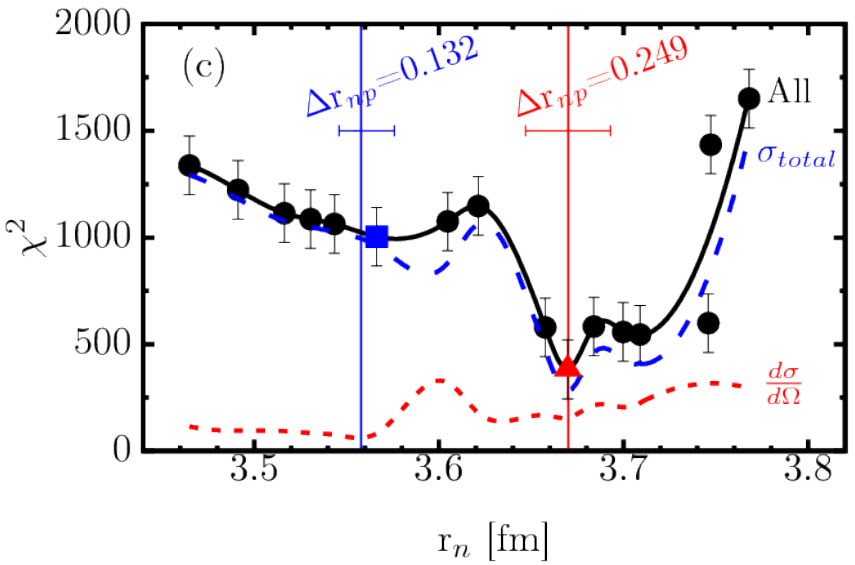
Neutron Stars



Medium Nuclei Skins Advantage: ^{48}Ca



Hagen et al. Nature 12 (2016) 186



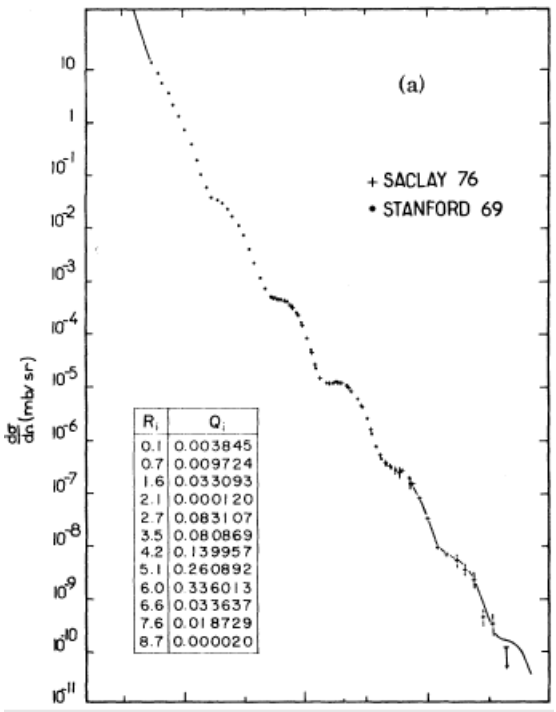
Mahzoon et al. PRL 119 (2017) 222503

- New state of the art predictions from microscopic models
- Significant disagreement between coupled cluster and optical model can be tested

Weak Force for Neutrons

What's new that we can do?
Look at weak-force interactions!
Primarily couples to neutron and (mostly) not proton!

$$Q_{\text{weak}}^{\text{proton}} \propto 1 - 4\sin^2\theta_{\text{W}} \approx 0.076, \quad Q_{\text{weak}}^{\text{neutron}} \propto -1$$



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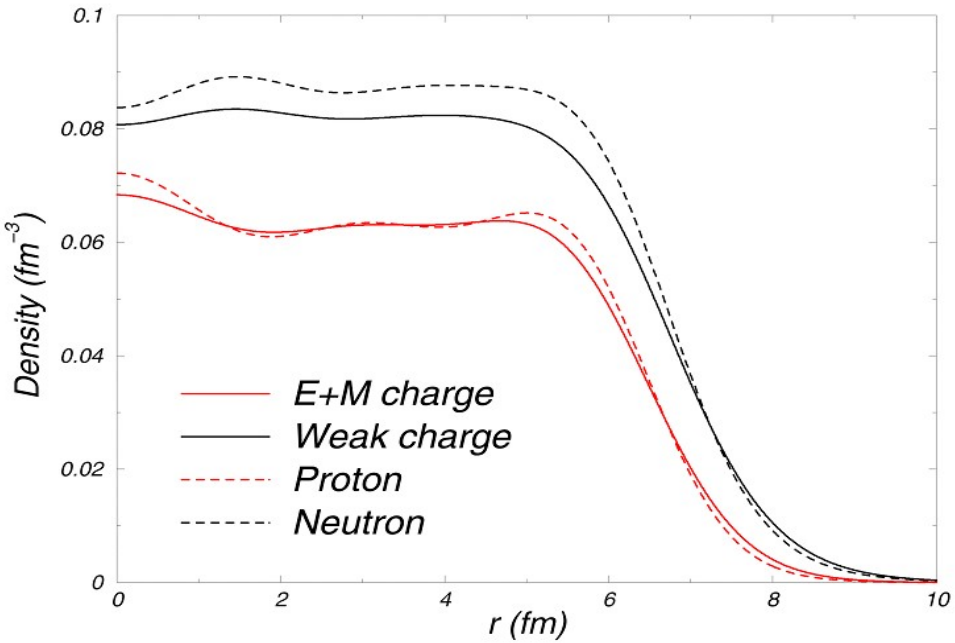
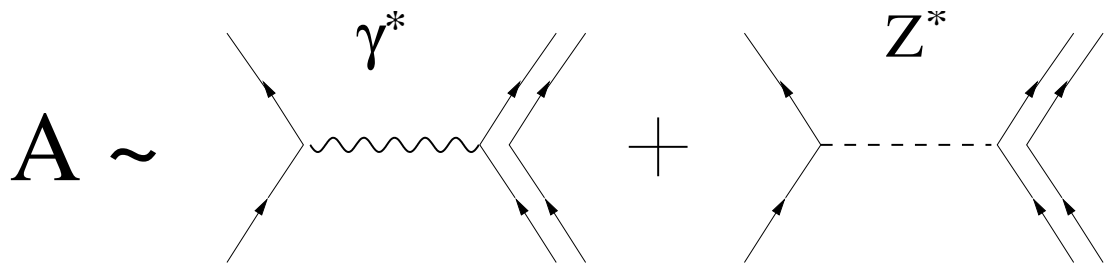
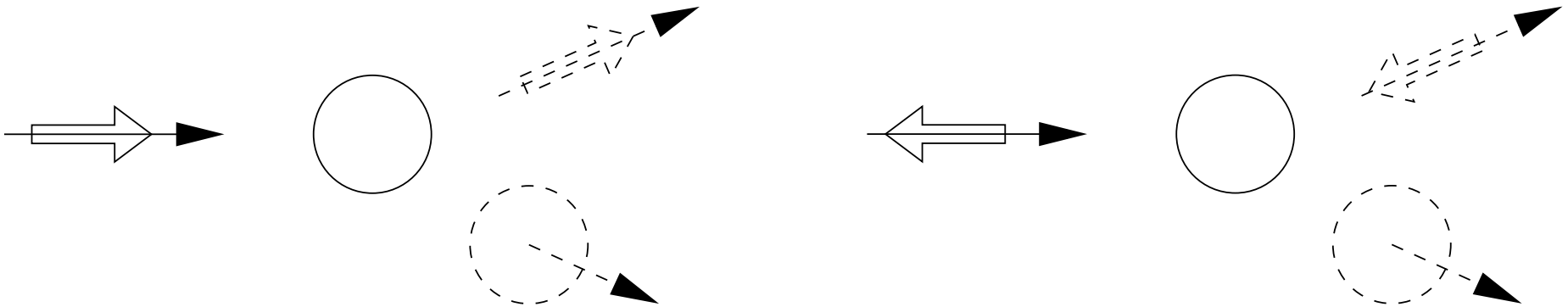


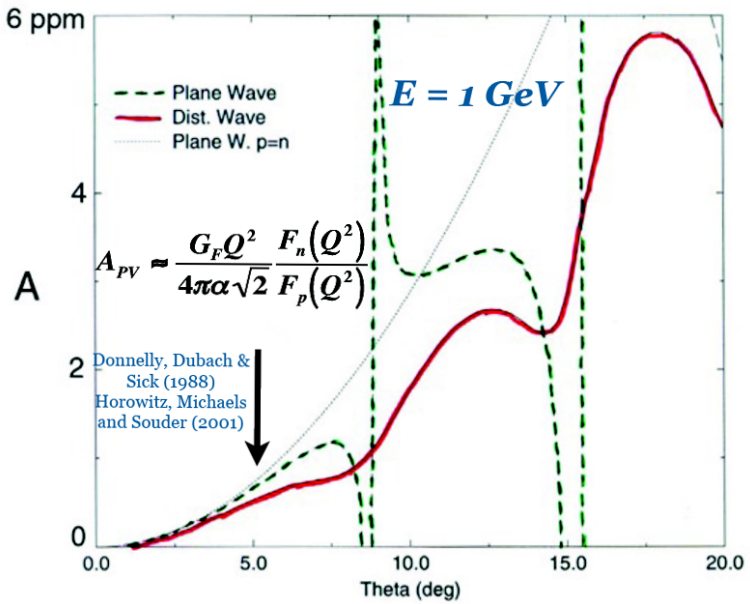
- We can use parity violation to pick out the weak interaction component over the electromagnetic

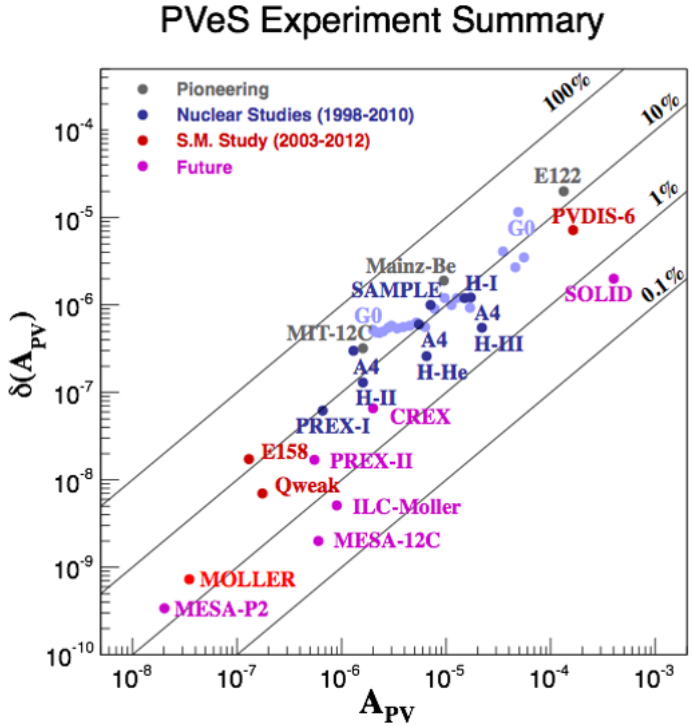




Rates are different if parity is violated

Measure *relative* rates in form of an asymmetry





$$A_{\mathrm{PV}} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \left[1 - 4\sin^2\theta_W - \frac{F_n(Q^2)}{F_p(Q^2)} \right]$$

- Higher order effects (Coulomb distortions) wash things out
- Optimized for for GeV beam, 5° $A \sim$ ppm
- Use two symmetric HRS with quartz integrating detectors

Near Future!

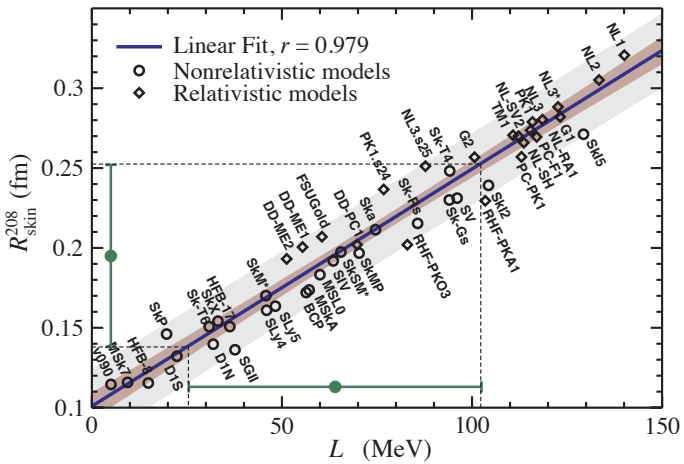
Experiments scheduled for summer!

PREX-II - ^{208}Pb

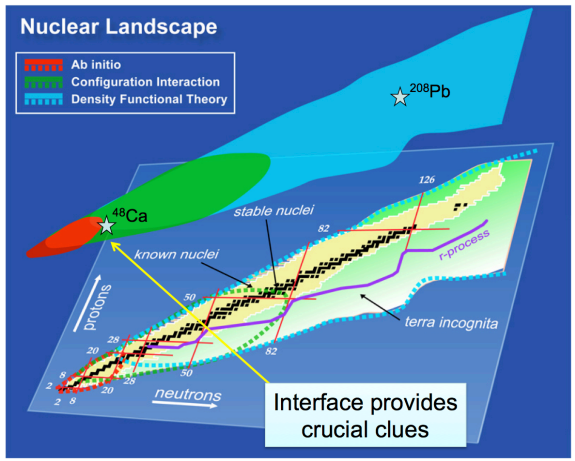
- Aims to each goal of $\delta R_n \sim 0.06$ fm
- Improved shielding and more advanced targets allow for full running
- Improved constraining systematics

CREX - ^{48}Ca

- Measurements on ^{48}Ca to 0.02 fm
- Gives broader reach over periodic table
- Contributing systematics slightly different
- $A \sim 40$ now within reach of microscopic calculations



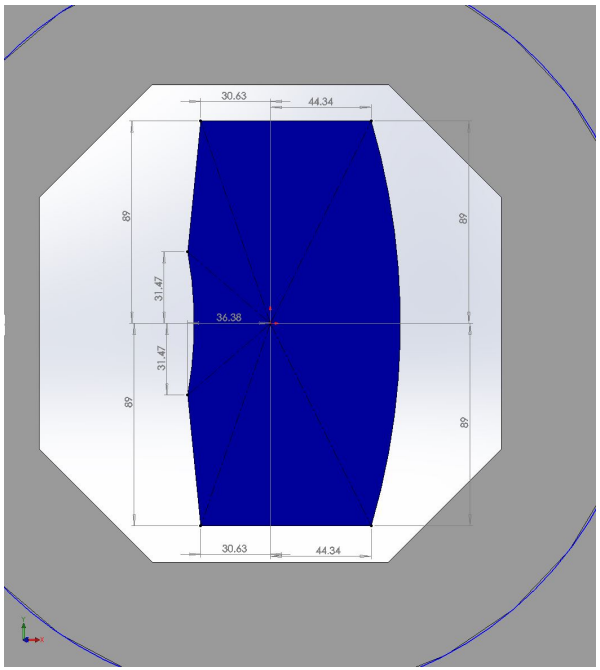
X. Roca-Maza *et al.*, PRL 106 252501 (2011)

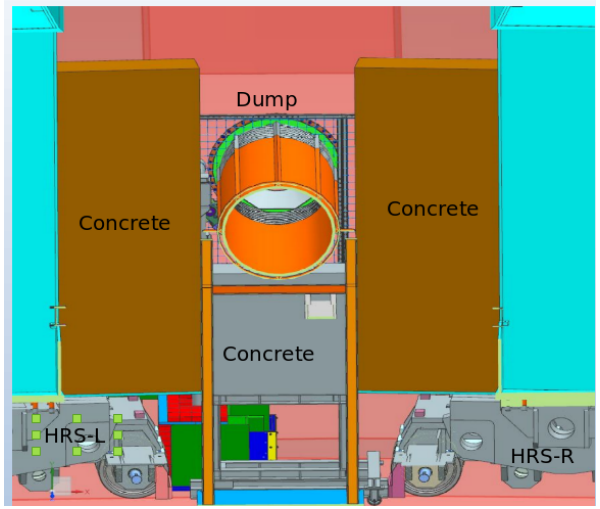


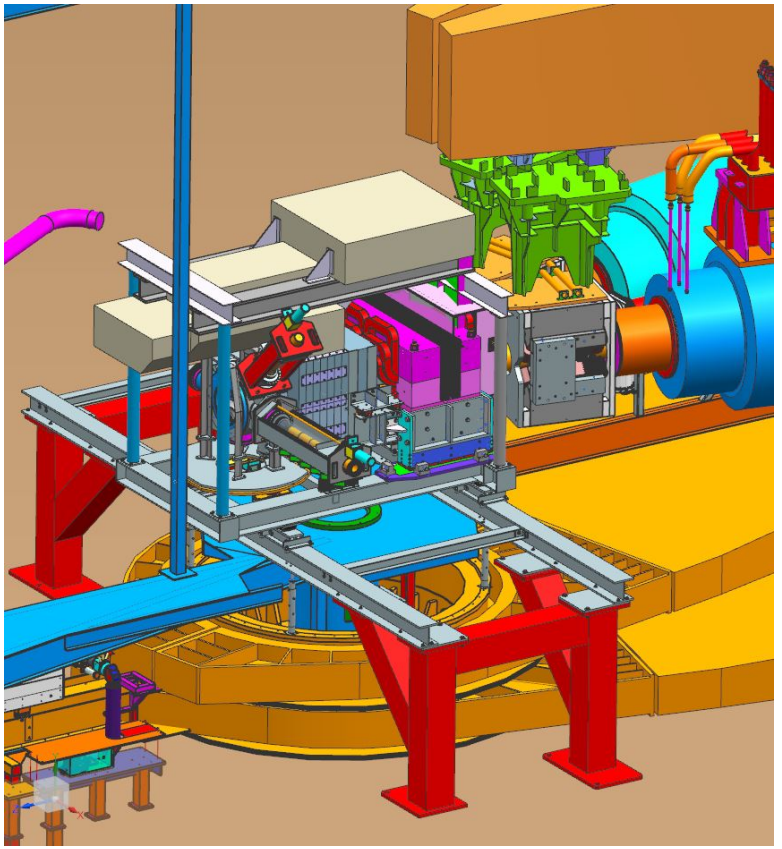
Schedule

- Installation to begin after APEX - March 18?
  - New target chamber
  - Septum magnet
  - Q1 collimators
  - Radiation shielding
  - Removing HRS detectors
  - Installation of experiment quartz and GEMs
- PREX Run, June 17 - Aug 18?
  - 950 MeV, up to 70 μA
- CREX Run
  - 2.1 GeV, up to 150 μA
  - Nov 1 - Dec 19
  - Feb 14 - Mar 25, 2020

Significant New Engineering

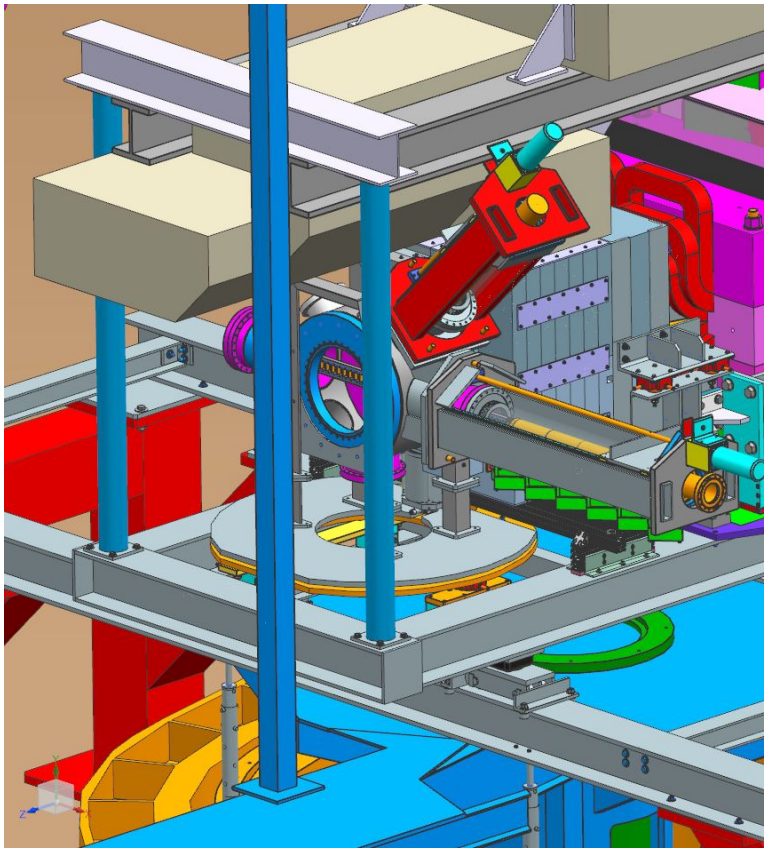


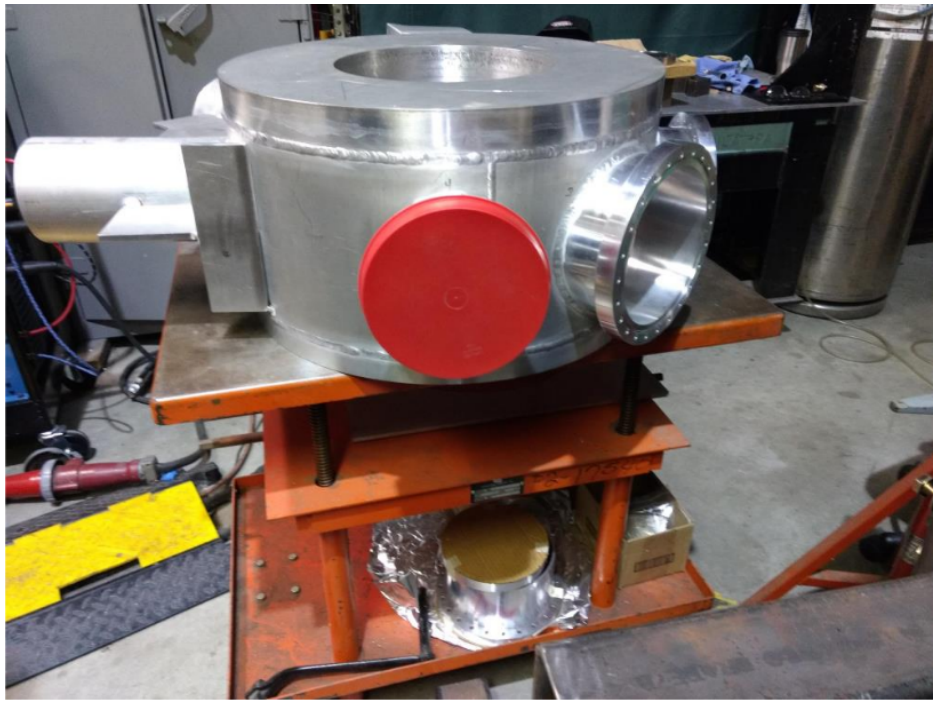




- Radiation collimation and magnetic shielding around beamline
- Support and shielding around target and dump
- New Q1 collimators

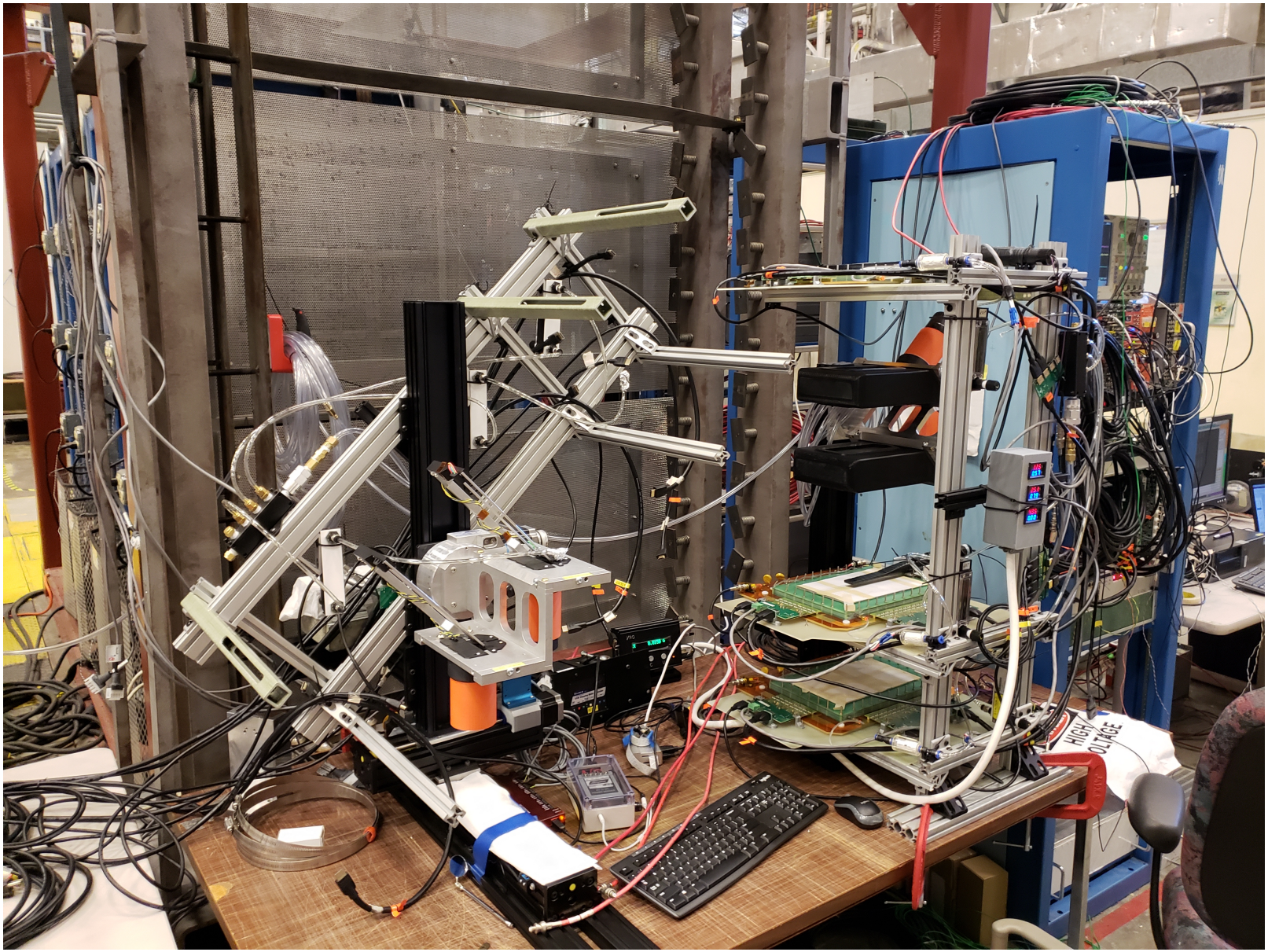
Targets





- Major development: New ^{48}Ca target
  - Proposal spec thickness, 96% pure, unoxidized
  - Recently new assay for impurities
- 10 ^{208}Pb targets with 0.25 mm diamond backing
- Chamber welded, work ongoing for ladders

Detectors



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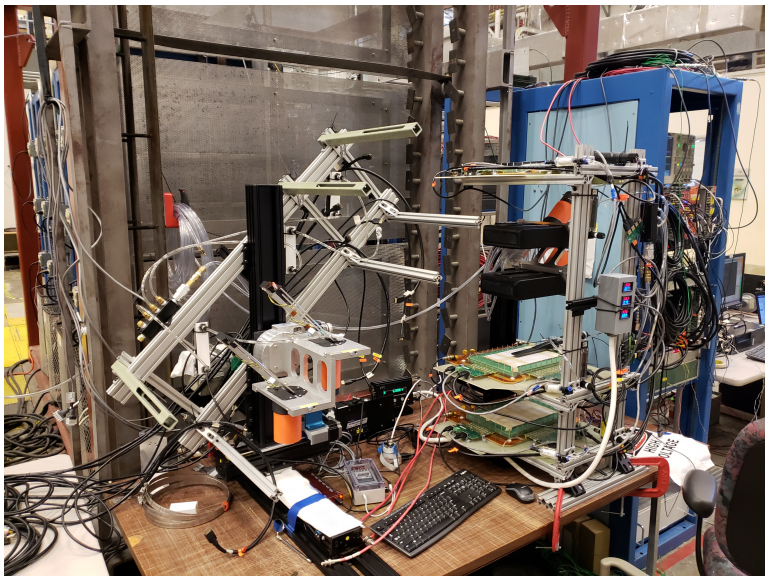
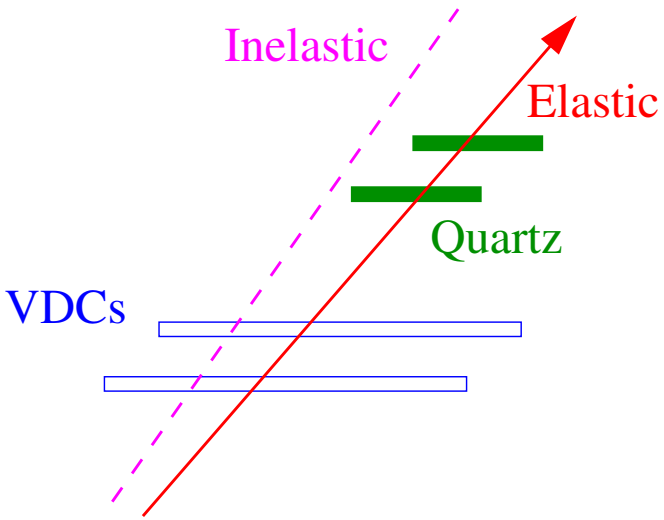
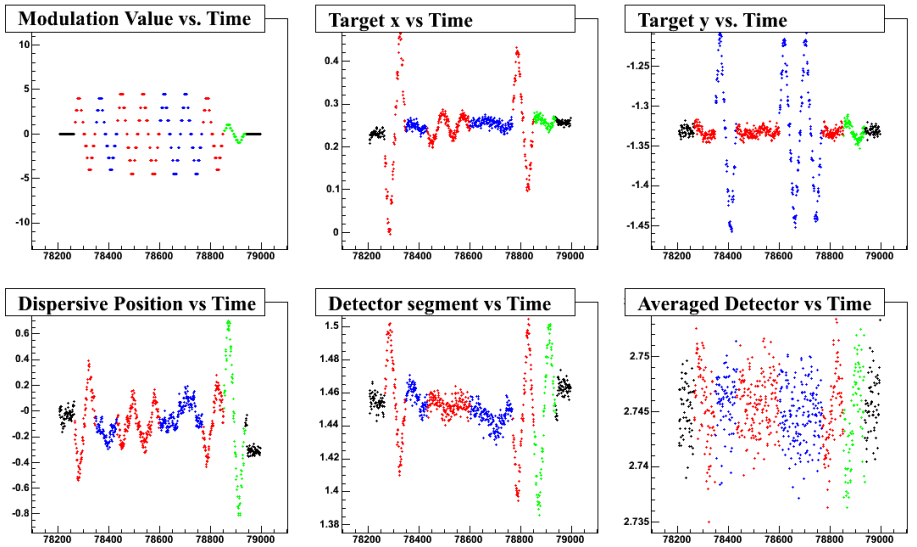




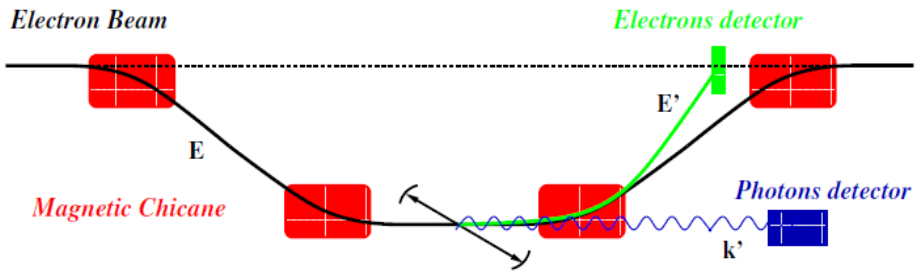
- Quartz detectors used for main measurement
- New detector stand constructed
- Additional detectors to better constrain A_T systematics
- Including six GEMs in each arm for high-rate acceptance measurements
- New small angle monitors

Polarimetry, DAQ, source beamline

- Major efforts in reestablishing
  - Parity and counting DAQ
  - Parity-quality source
  - Beamline monitoring
  - Beamline modulation (dithering)



- Using both Compton and Moller polarimetery
  - On track for 1%-level systematics
  - In beam tests after APEX expected



Summary

- Neutron skins contain information on asymmetric nuclear matter including neutron star structure
- Parity violating electron scattering gives neutron distributions using weak force
- The PREX-II and CREX programs aim to measure δR_n to a precision of 0.06 fm and 0.02 fm respectively next year
- On track on all fronts to being ready for start in June