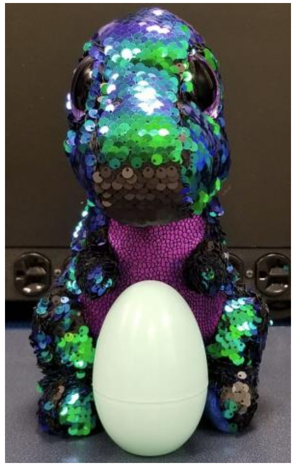
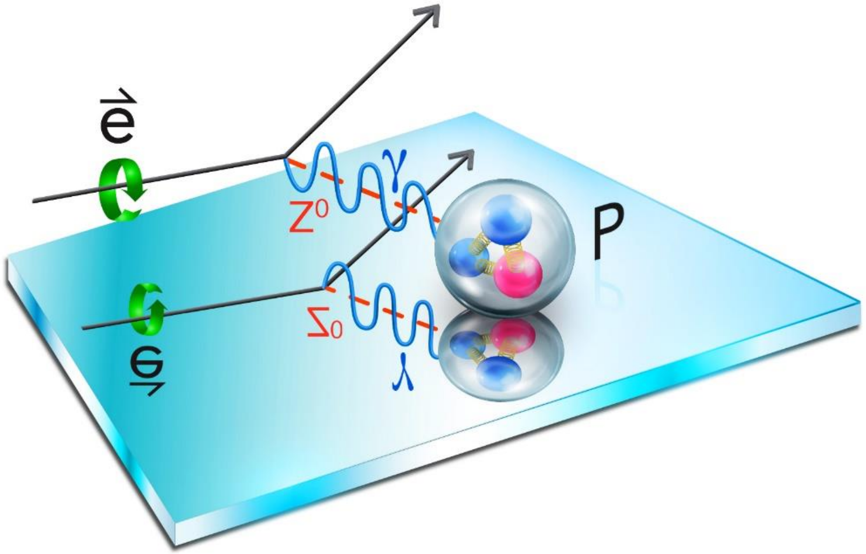
PREX/CREX Overview



Juliette Mammei

for the PREX and CREX Collaborations



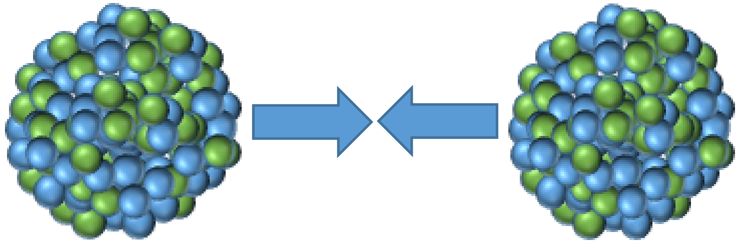
Jefferson Lab

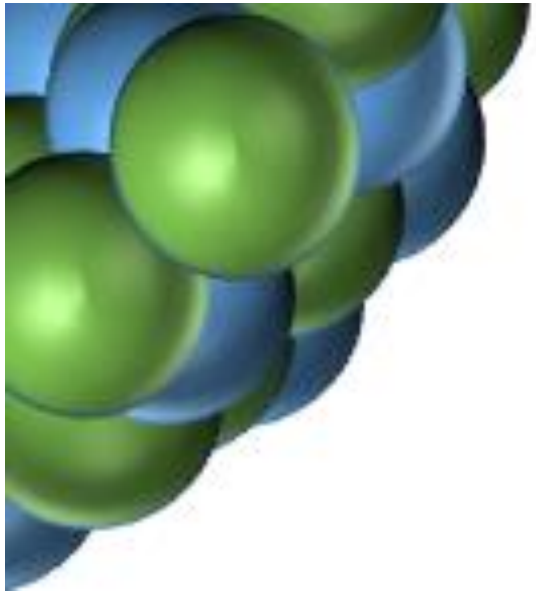
NSERC
CRSNG

University of Manitoba

Parity-violating electron scattering

Strong interaction uncertainties in other measurements, like HIC

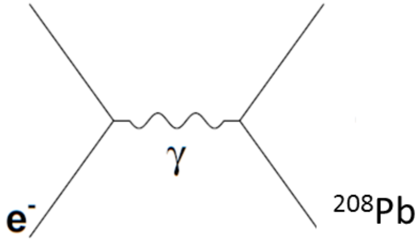


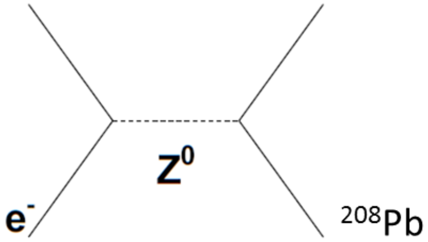


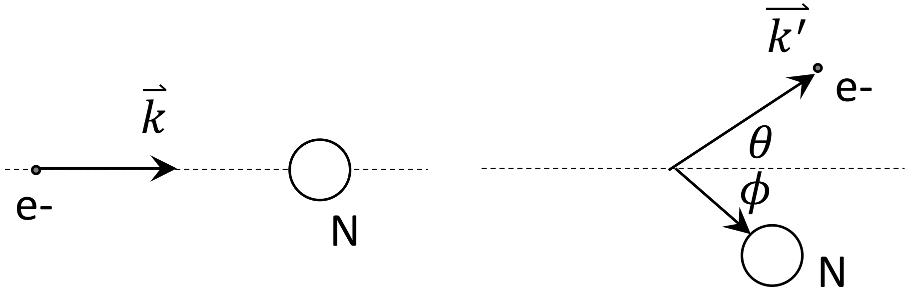
Electrons with different helicities "see" different potentials for the nucleus because of parity-violation in the weak interaction

In electron scattering the probe doesn't interact via the strong force

Does interact via the E&M and weak forces







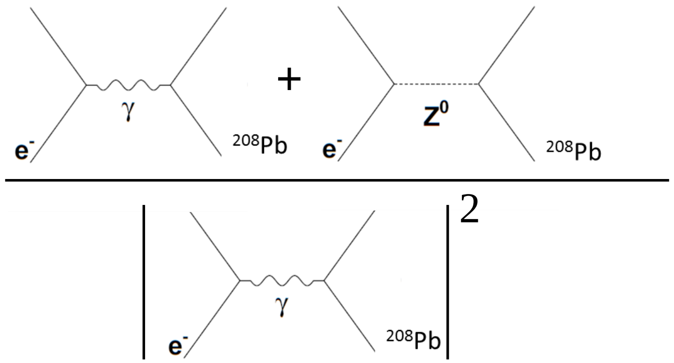
$$q^2 = (\vec{k'} - \vec{k})^2$$

Elastic scattering

$$\Rightarrow -q^2 = Q^2 = 4EE'sin^2\theta$$

Neutron skin with PVES

$$A_{PV} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-} \approx$$

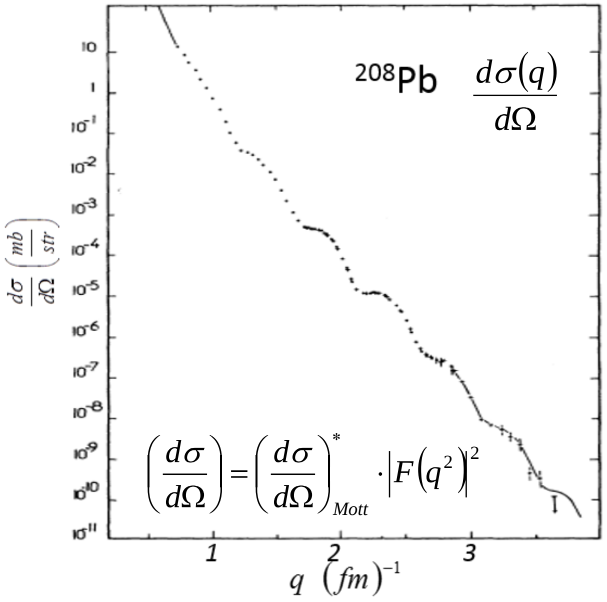


$$= \frac{G_F Q^2}{2\pi\alpha\sqrt{2}} \left[\overbrace{1 - 4\sin^2\theta_W}^{\approx 0} - \frac{F_n(Q^2)}{F_p(Q^2)} \right]$$

The Fourier transform of the weak "form factor" $F_W(Q^2)$ gives the weak charge density as a function of radius, just as it does for the charge form factor

$$Q^p_{weak} = 1 - 4\sin^2\theta_W \approx 0$$

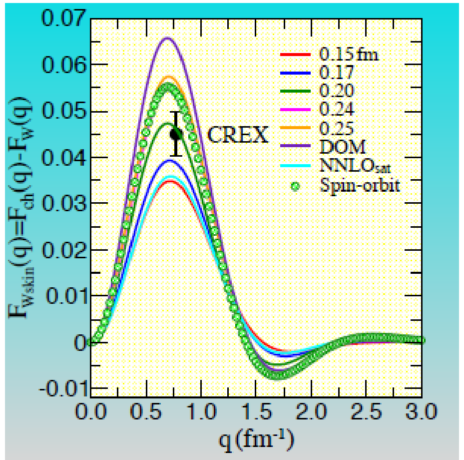
$$Q^n_{weak} = -1$$

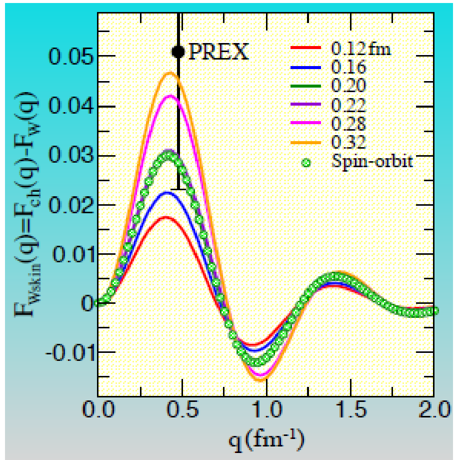


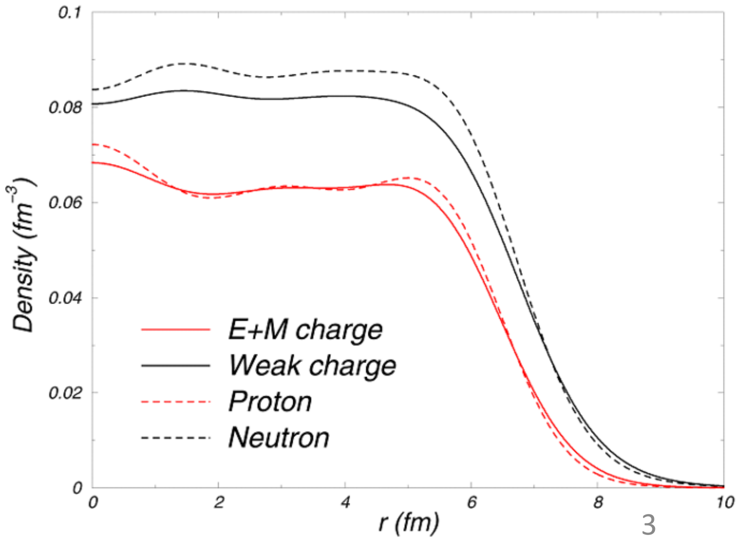
$$F_n(Q^2) = \frac{1}{4\pi}\int d^3r\ j_0(qr)\ \rho_n(r)$$

Measurement of $F_n(Q^2)$ at a single Q^2 translates to a measurement of R_n via mean-field nuclear models

At low Q^2 there is a tight correlation between R_n and $F_n(Q^2)$







Equation of State of Neutron Matter

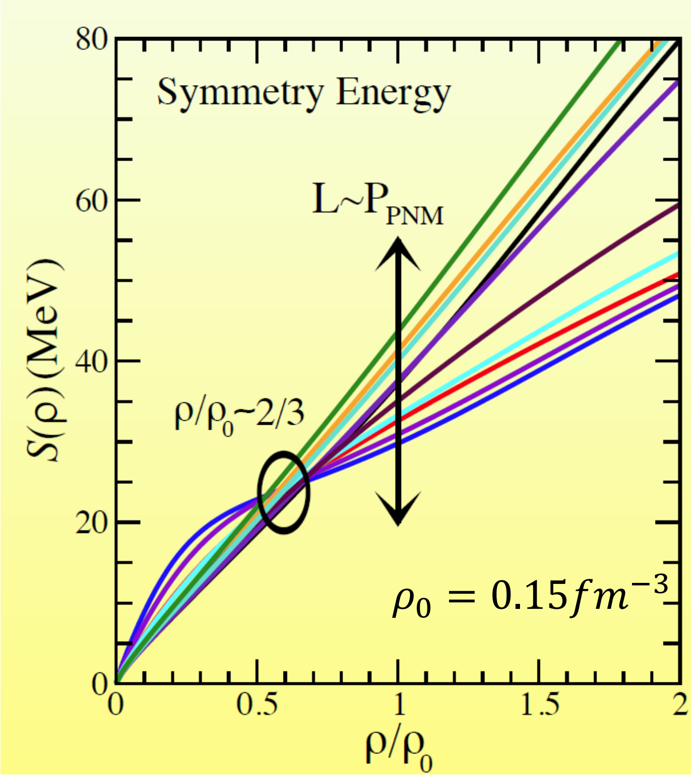
E/A for symmetric nuclear matter — Symmetry energy

$$\varepsilon(\rho, \alpha = 1) \approx \varepsilon_0(\rho) + \alpha^2 S(\rho) \approx \epsilon_0 + Lx$$

EOS of pure neutron matter

$$\alpha = (N - Z)/A$$

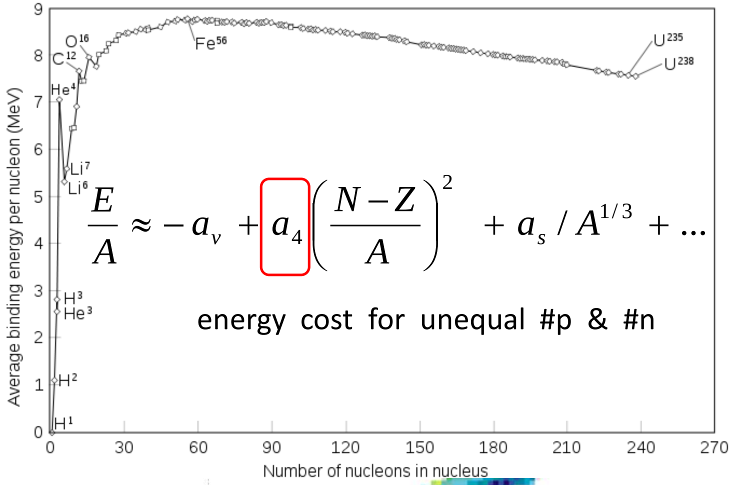
$$x = (\rho - \rho_0)/3\,\rho_0$$

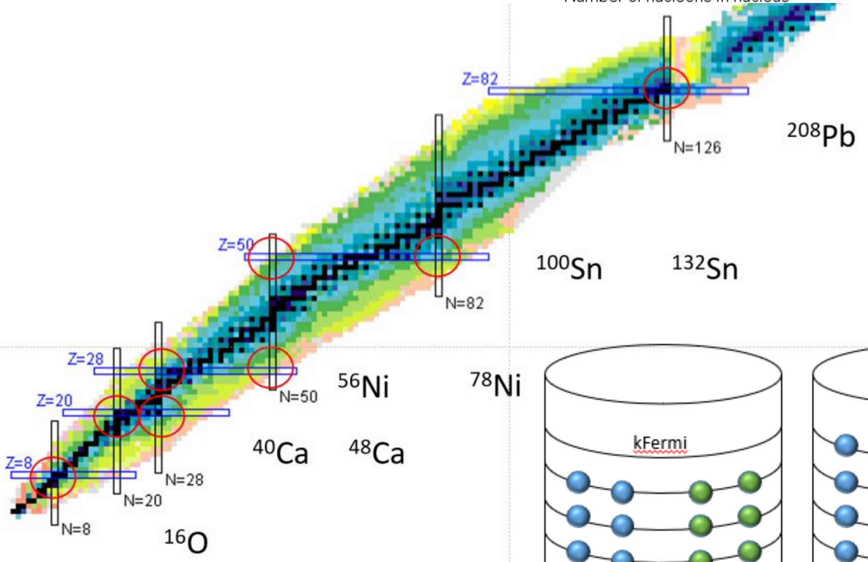


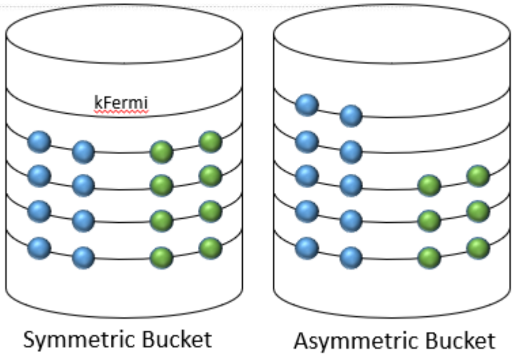
$$P_0 = \left(\rho^2 \frac{\partial \varepsilon_{PNM}}{\partial \rho}\right)\bigg|_{\rho = \rho_0} \approx \rho_0 \frac{L}{3}$$

Pressure of pure neutron matter

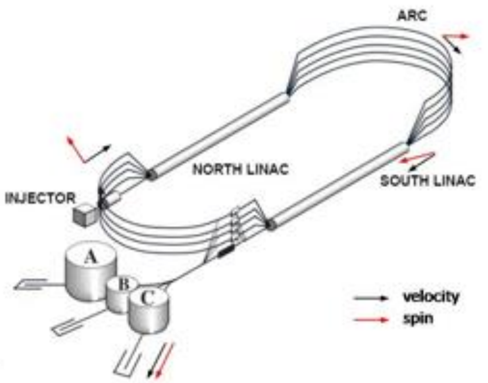
Unconstrained by isoscalar sector measurements (~symmetric nuclear matter, including nuclear binding energies, etc.)







Measuring A_{PV} with ES



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itors

ter

polarized beam

target

cooling

position

spectrometer

Collimators

Magnets

detectors

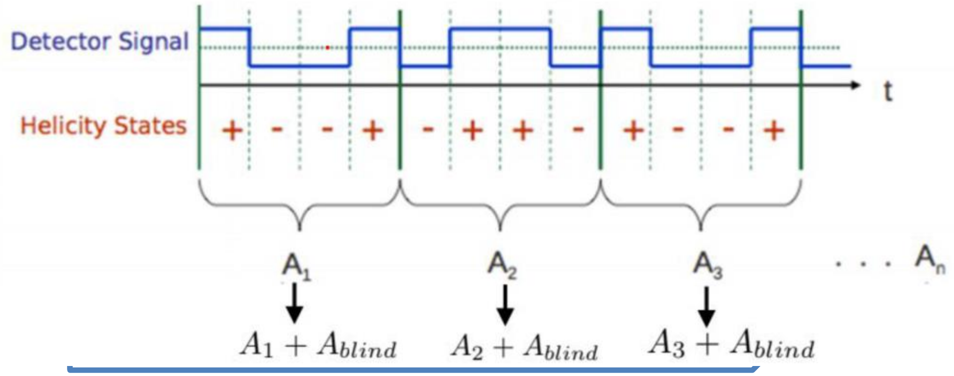
main detector

tracking detectors

background determination

luminosity monitors

electronics

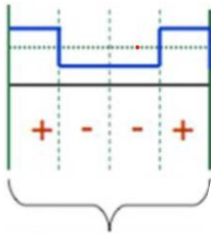


A_{PV}

$$A_{sig} = \frac{A_{corr} - A_{back}\, f_{back}}{f_{sig}}$$

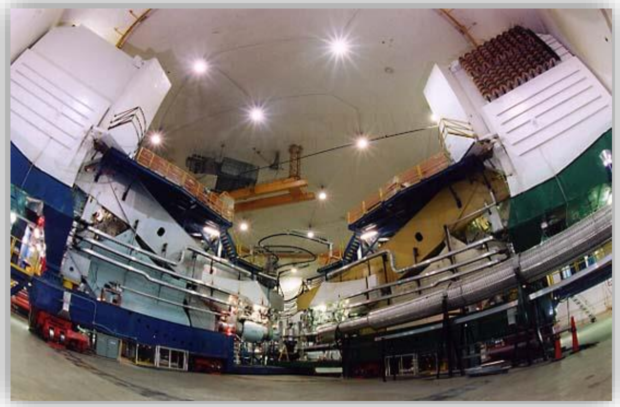
$$A_{corr} = A_{meas} - \sum_{i=1}^{N} \frac{1}{2Y}\left(\frac{\partial Y}{\partial P_i}\right)\Delta P_i$$

where $\Delta P_i = P_+ - P_-$



$$A_{meas} = \frac{Y_+ - Y_-}{Y_+ + Y_-}$$

Hall A High resolution spectrometers

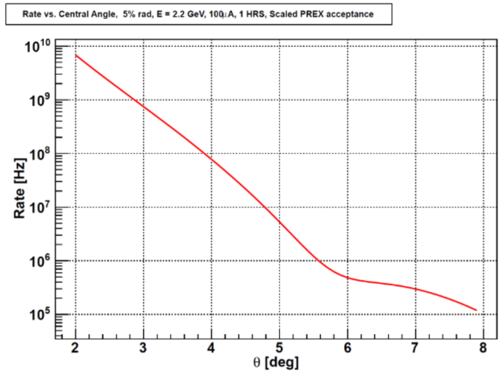


1 (2.2) GeV electron beam, 50-70 μA

high polarization, ~89%

helicity reversal at 120 Hz

PREX (CREX) Parameters

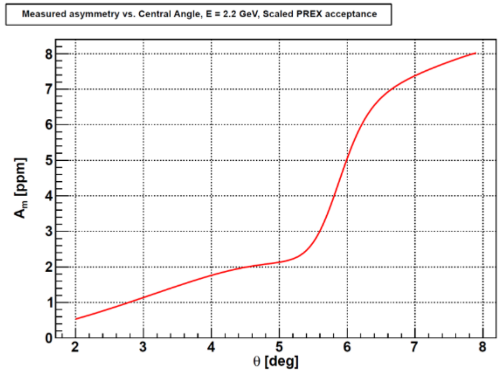


0.5 (5) mm thick Pb (Ca) target

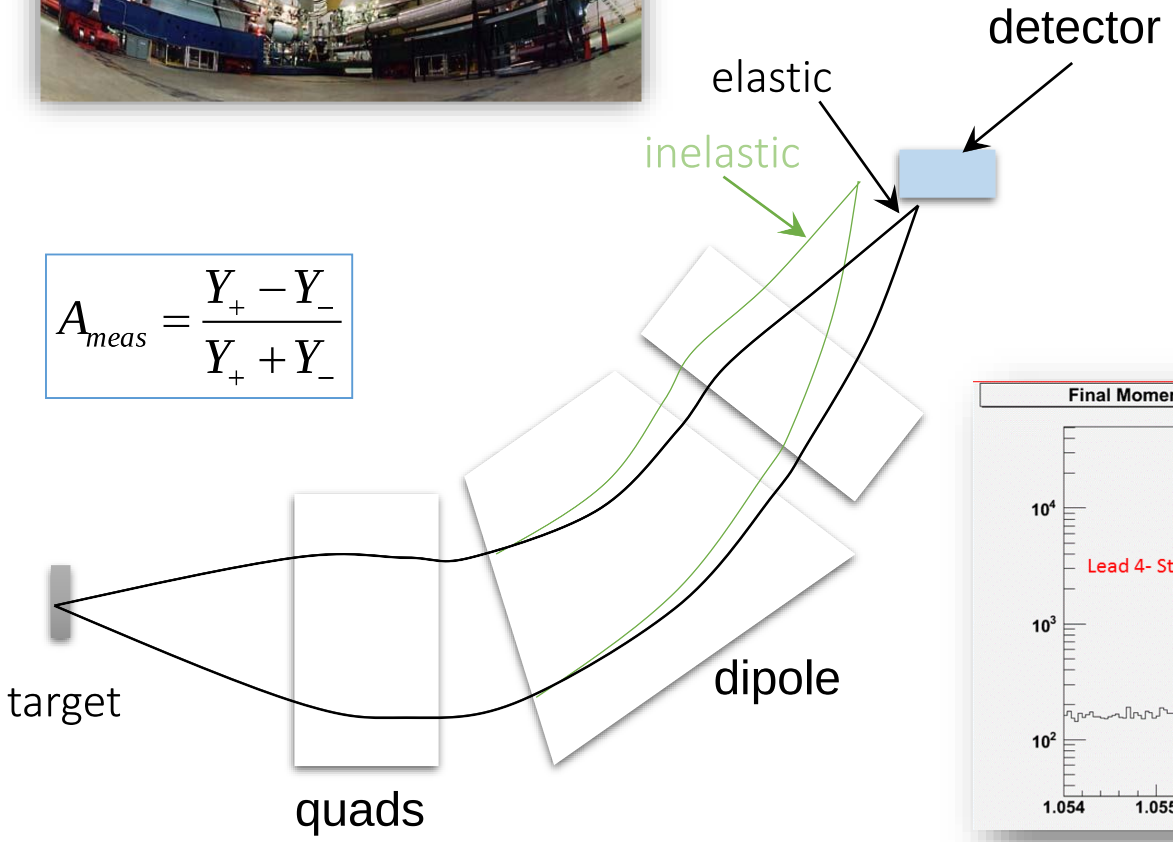
5° (4°) scattered electrons

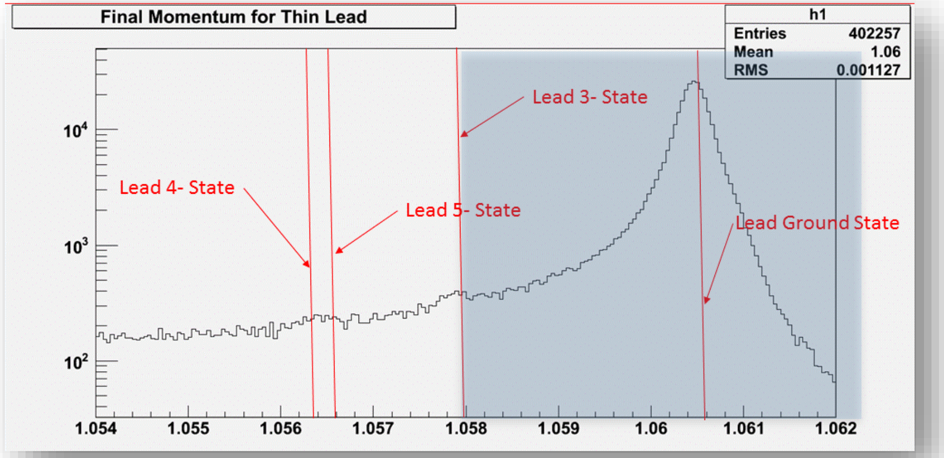
Q^2 =0.0088 (0.022) GeV^2/c^2

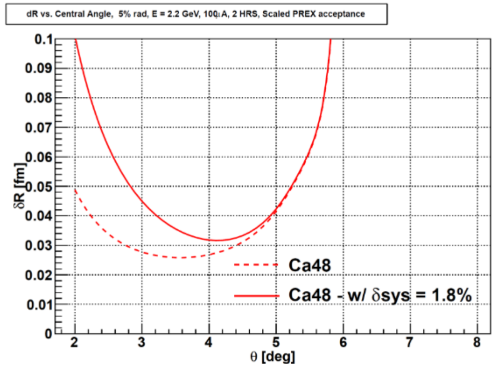
thick and thin quartz detectors



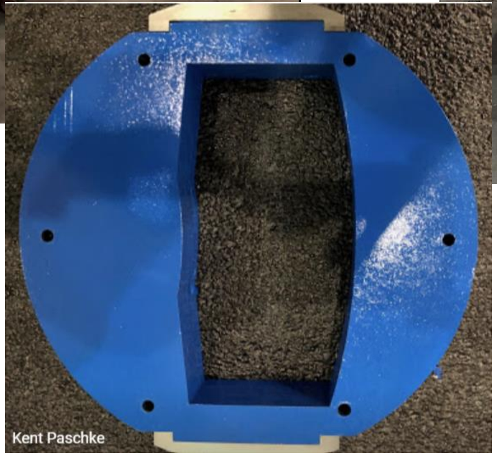
$$A_{meas} = \frac{Y_+ - Y_-}{Y_+ + Y_-}$$







Special equipment

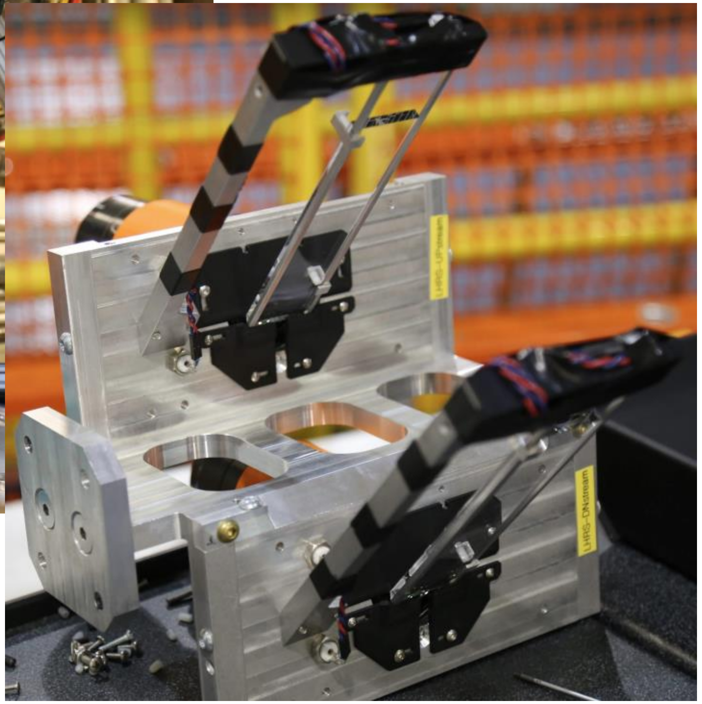


Septum magnet needed because to reach the low angles

Vacuum vessel to transport scattered electrons in vacuum to detector hut

Precision collimators to define the acceptance

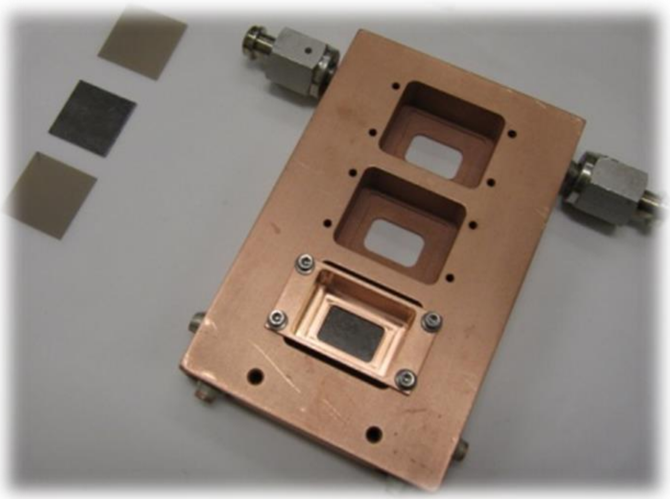
Special equipment, cont.

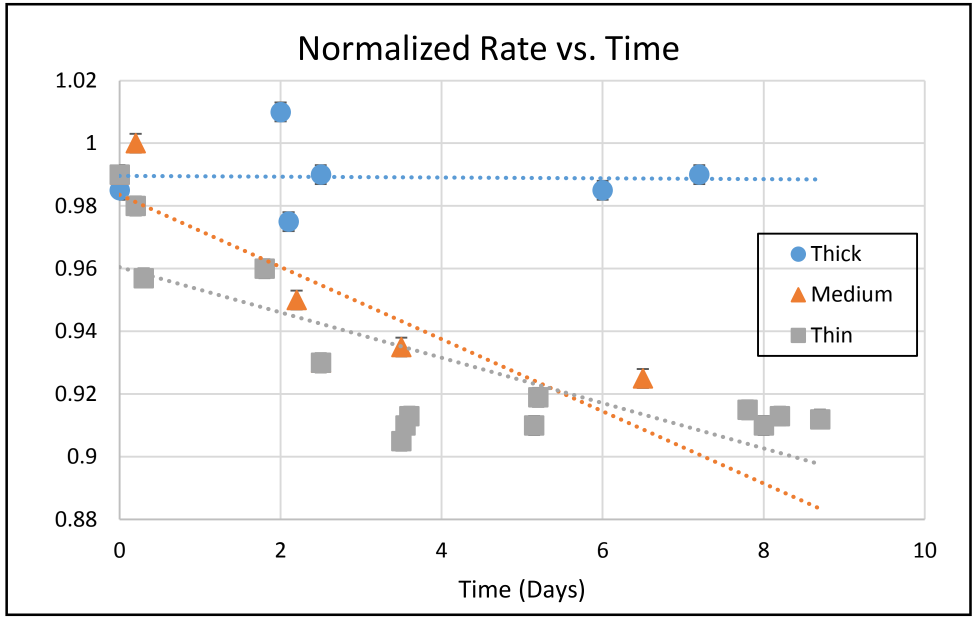


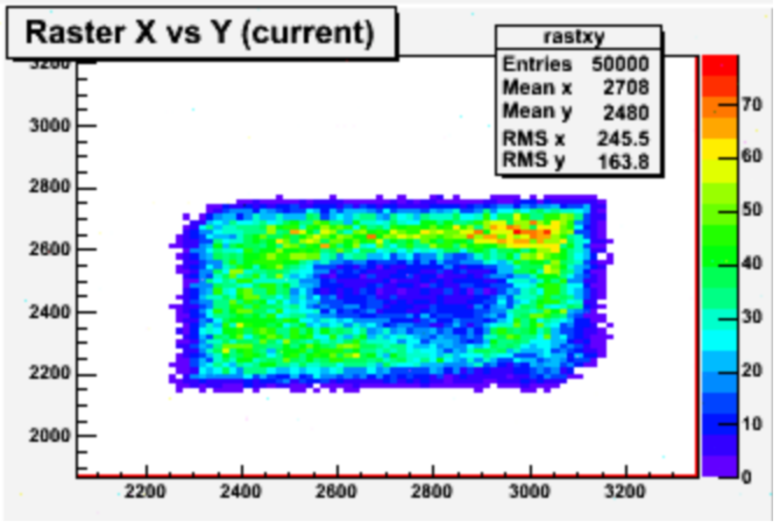
Integrating detectors (reduce deadtime effects)

Thick and thin quartz bars (different systematics)

Targets





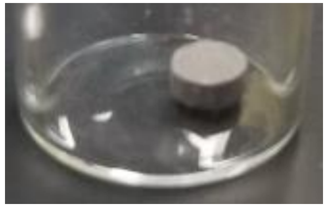


In PREX I, Pb target with thin diamond backing (4.5% bkgd) degraded fastest

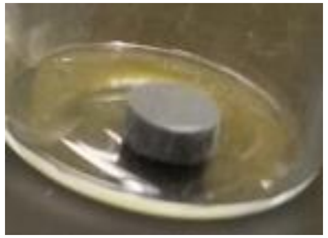
Target with thick diamond (8% bkgd) ran well and did not melt at 70 uA

Natural Ca used in testing oxidation

sanded

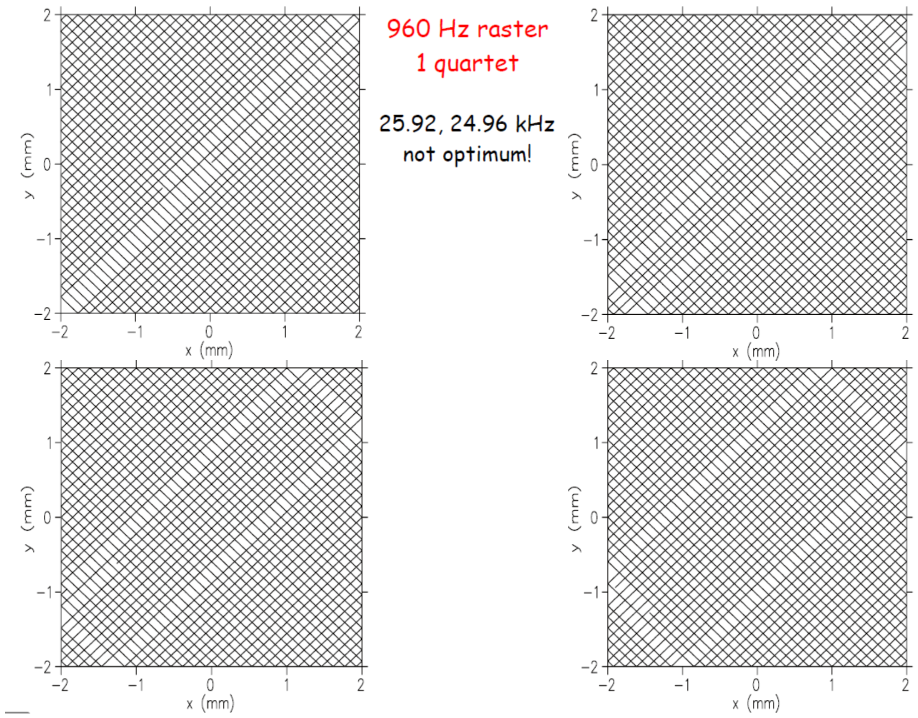


Oxidized 1 hour



Oxidized 24 hours

Target performance



Solutions:

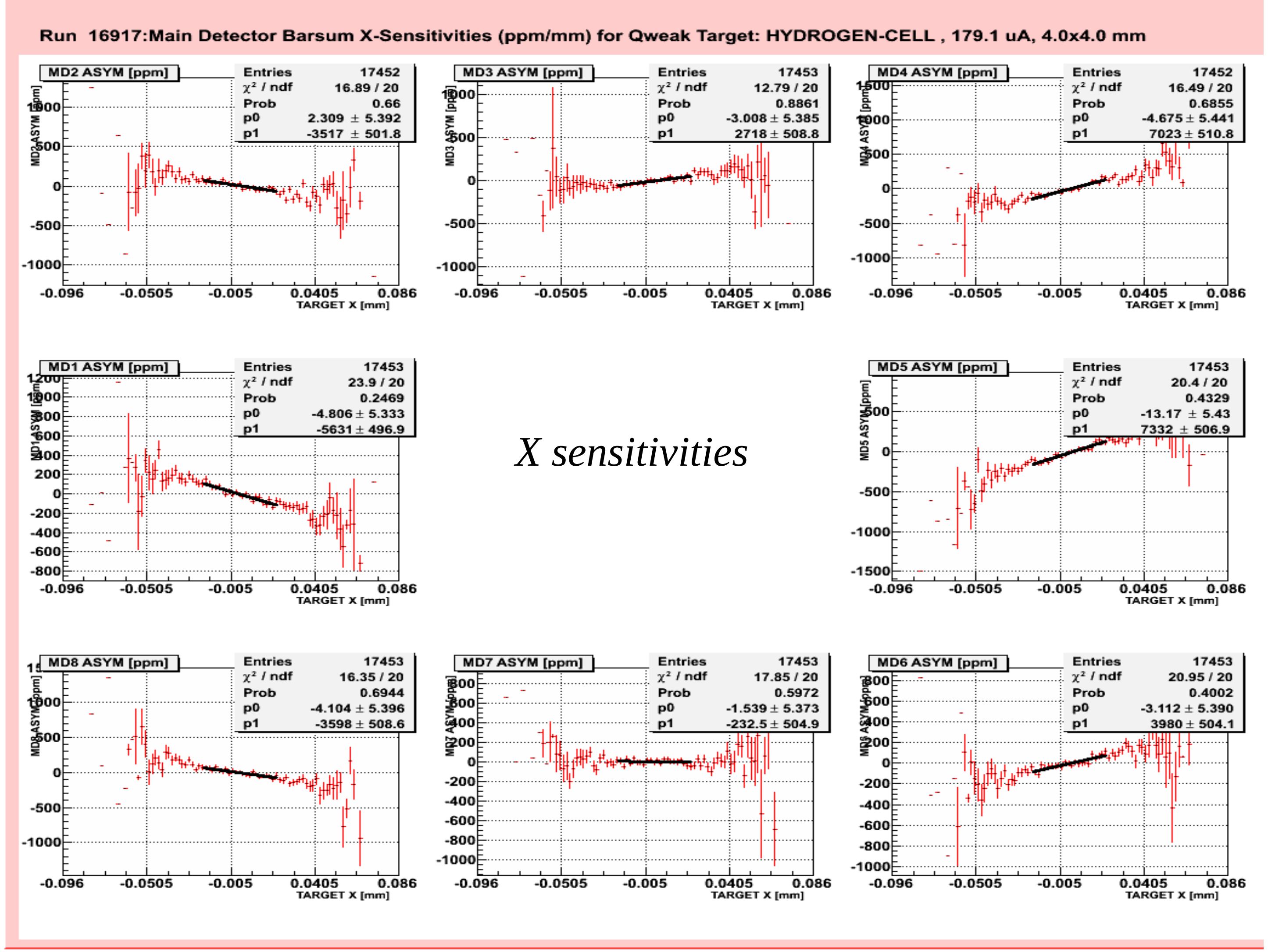
Sync the raster
Run with 10 targets

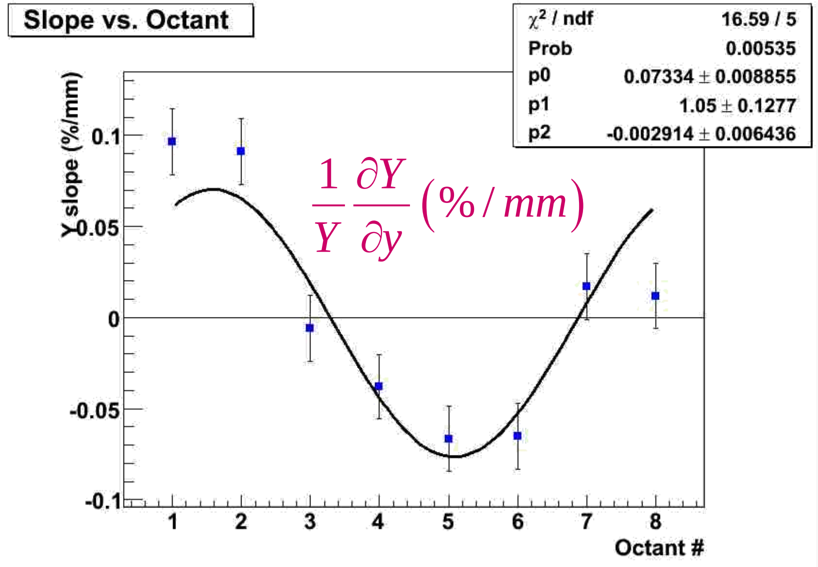
Acquire new ^{48}Ca
Don't expose it to air

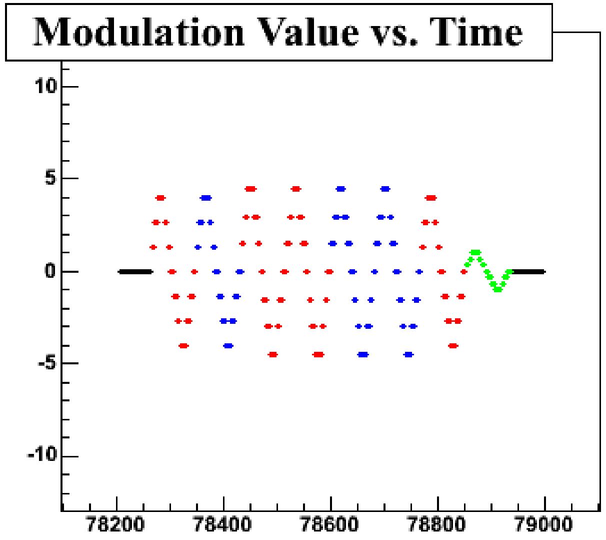
Calcium target for CREX is currently in the scattering chamber

Vacuum is being monitored VERY closely

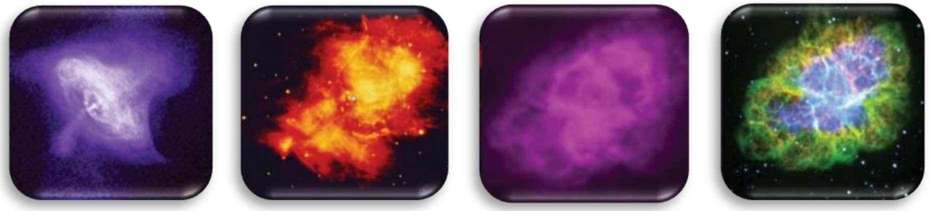
Slopes from natural beam motion





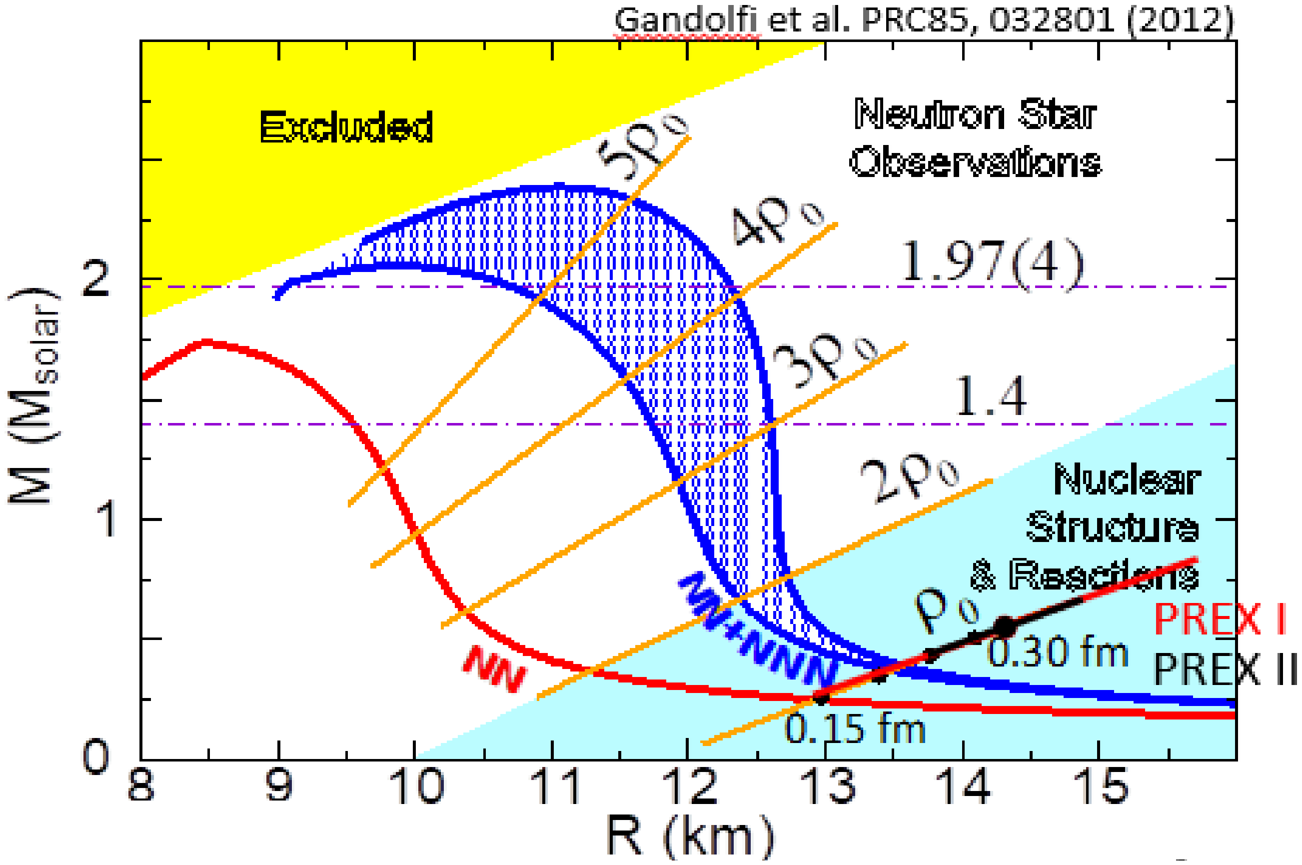


Connecting heaven and earth

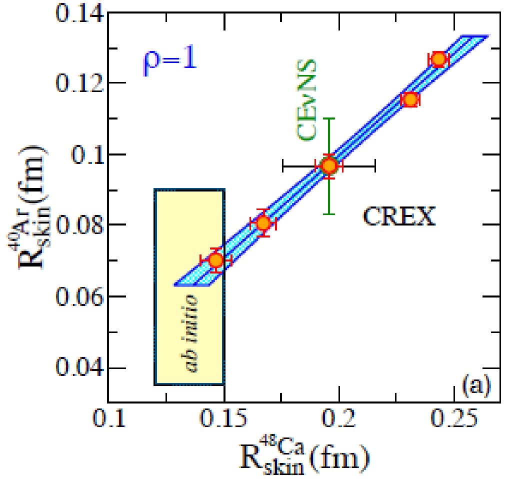


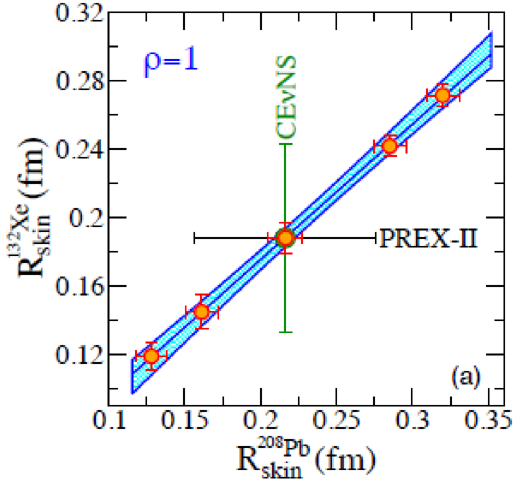
Crab Nebula (X-ray, infrared, radio, visible)

If PREX II confirms that R_{skin} is large and LIGO-Virgo that NS-radius is small, this may be evidence of a softening of the EOS at high densities (phase transition?)

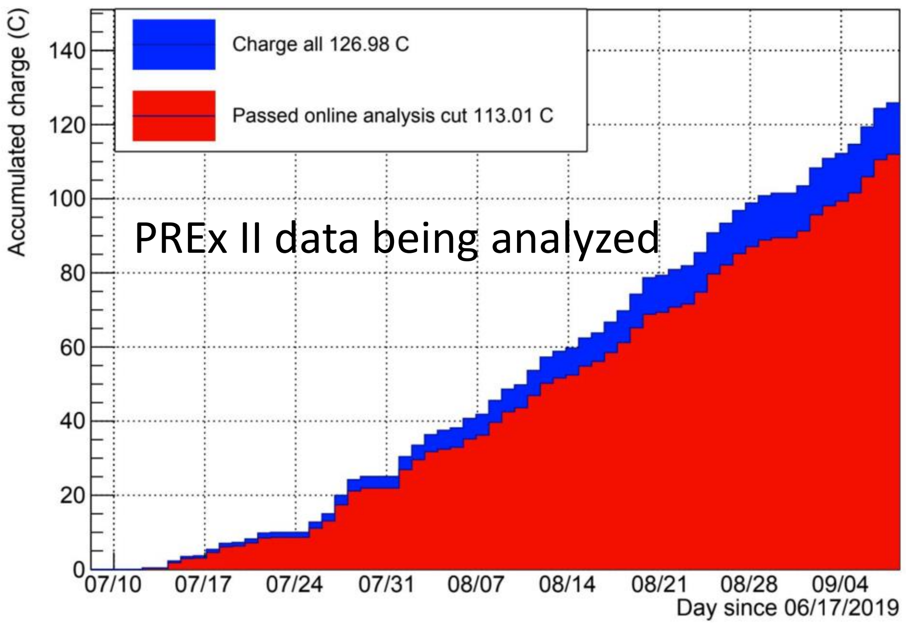


Gravitational



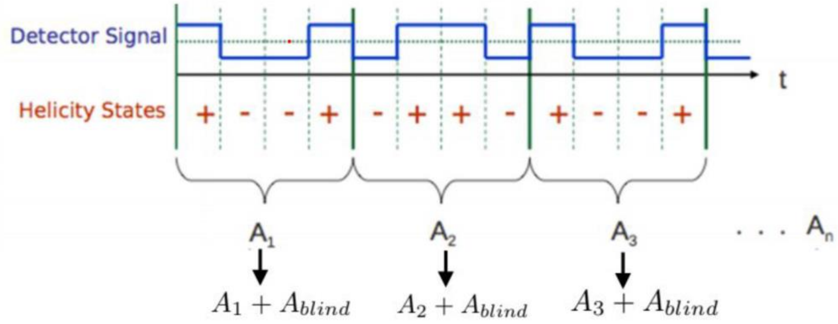


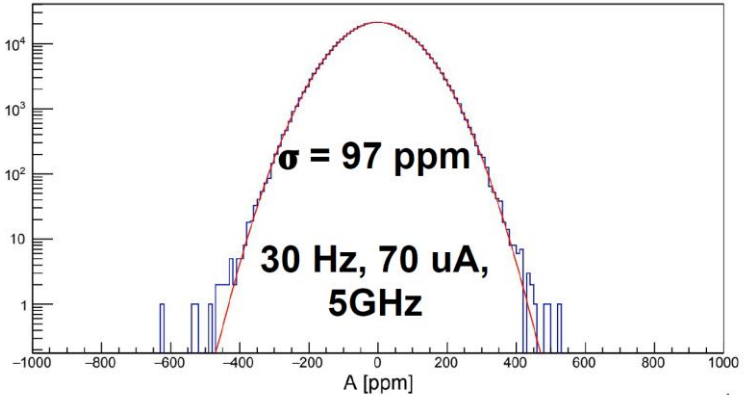
PREx II/CREX status – happening now!



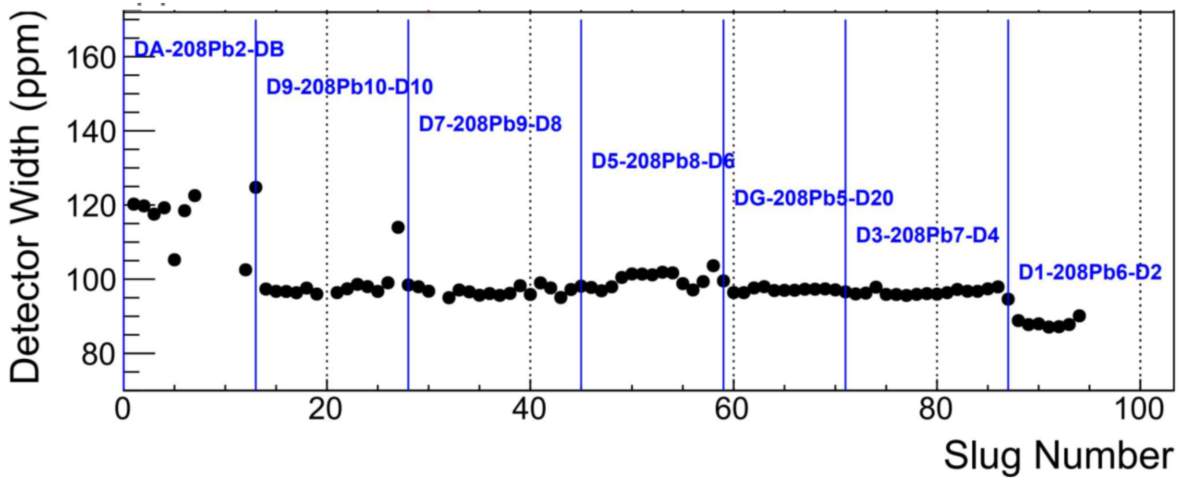
The detector system performed really well being able to take ~2.5GHz on a 10 x 3.5 cm piece of quartz in each arm

$$\sigma_A = \left(\frac{1}{flip\ rate} \times I\ (\mu A) \times R\ (Hz/\mu A) \times \#flips\ \times \#\ dets \right)^{-1/2}$$





- Before beam corrections our combined detector widths were on the level of 200-300 ppm
- Regression allowed us to remove the added noise and gave us rock solid ~100 ppm widths throughout the run



CREx run starts soon!