C-REX : Parity-Violating Measurement of the Weak Charge of ^{48}Ca to an accuracy of 0.02 fm

Spokespersons:
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Seamus Riordan (contact person)
Paul Souder

Elastic scattering -- parity-violating asymmetry -- from ^{48}Ca
at 1-pass energy using HRS + septum $E = 2.2\, GeV,\ \theta = 4^0$

Proposal

http://hallaweb.jlab.org/parity/prex/c-rex2013_v7.pdf

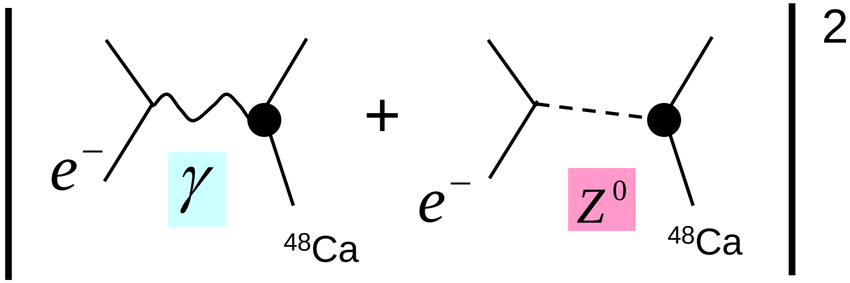
Recent Article

C.J. Horowitz, K.S. Kumar, R. Michaels Eur. Phys. J. A **50**; (2014) 48

Parity Violating Asymmetry

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

$\sigma \approx$



A_{PV} from interference

Parameter of Proposal	Value
Measured asymmetry (P_e x A)	2 ppm ("big")
Beam Energy	2.2 GeV (1-pass)
New Equipment	4^0 septum, ^{48}Ca target
Rates per HRS	120 MHz (similar to HAPPEX-2)
Stat. Error in Asy	2.4 % (requires 1% polarimetry !)
Systematic Error in Asy	1.2 % (includes polarimetry)
Error in R_N	0.02 fm ←→ 0.6 %
Beam current	150 uA aggressive !
Beam Time Request	45 days (includes 10 days overhead)

C-REX (& PREX) : Z^0 of weak interaction : sees the neutrons

	proton	neutron
Electric charge	1	0
Weak charge	0.08	1

T.W. Donnelly, J. Dubach, I. Sick
Nucl. Phys. A 503, 589, 1989

C. J. Horowitz, S. J. Pollock, P. A. Souder, R. Michaels
Phys. Rev. C 63, 025501, 2001

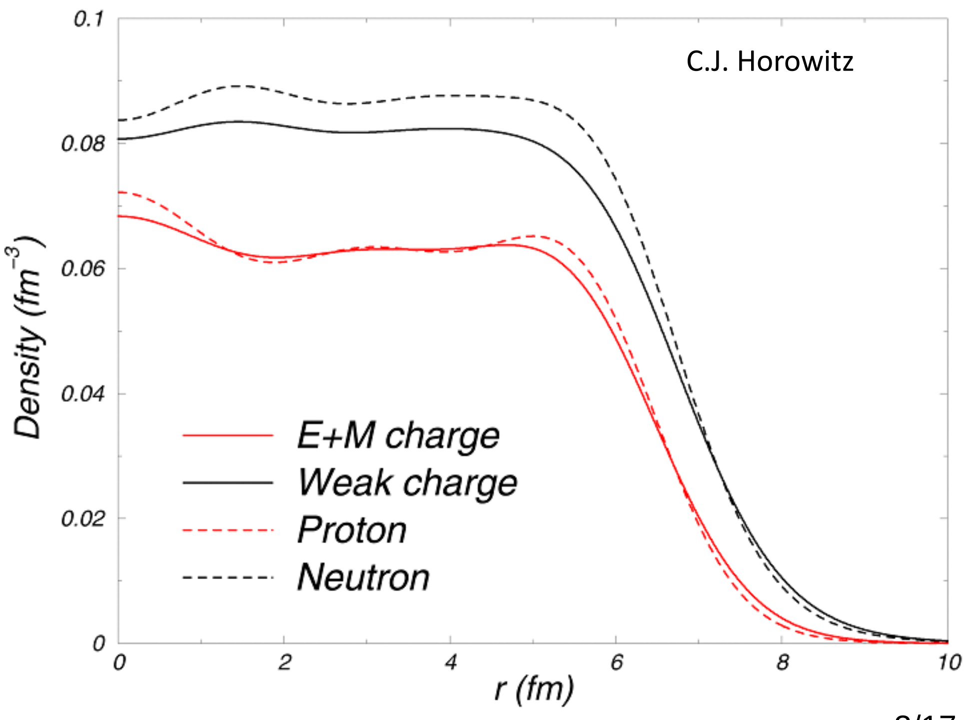
^{208}Pb

Neutron form factor

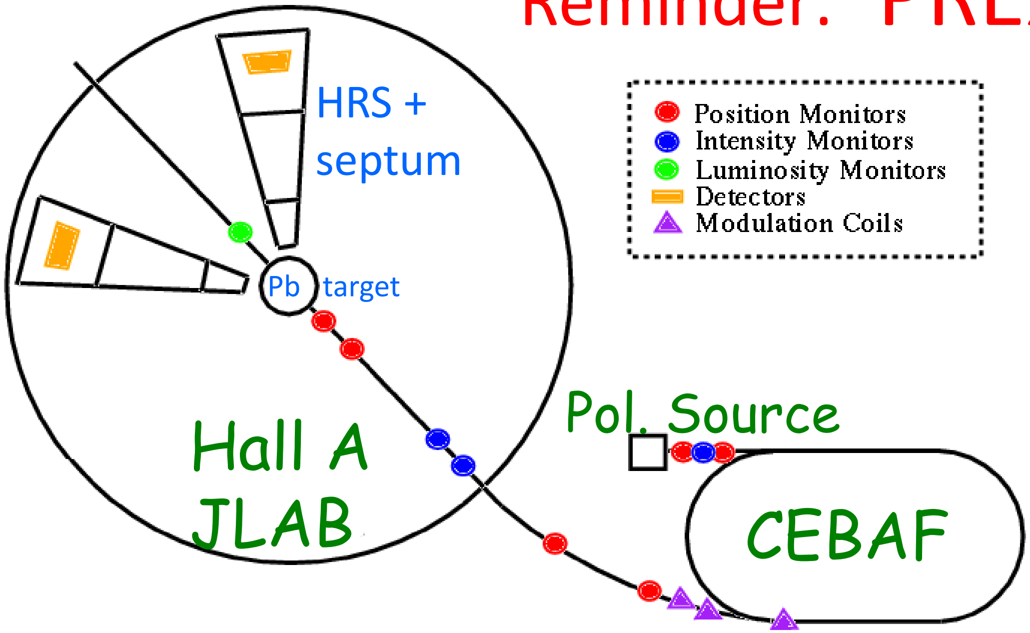
$$F_N(Q^2) = \frac{1}{4\pi} \int d^3r \; j_0(qr) \; \rho_N(r)$$

Parity Violating Asymmetry

$$A = \frac{G_F Q^2}{2\pi\alpha\sqrt{2}} \left[\underbrace{1 - 4\sin^2\theta_W}_{\approx 0} - \frac{F_N(Q^2)}{F_P(Q^2)} \right]$$



Reminder: PREX-I



Results

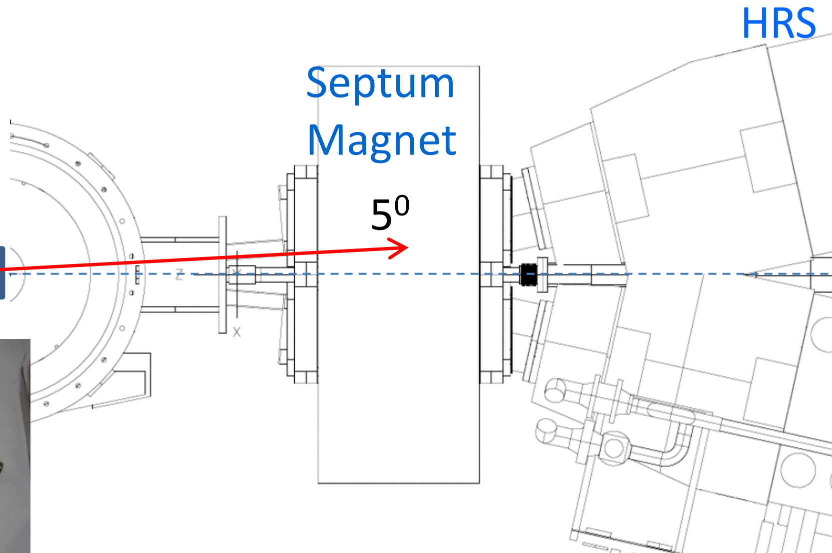
PRL 108 (2012) 112502

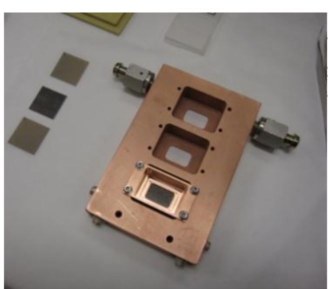
Physics Asymmetry

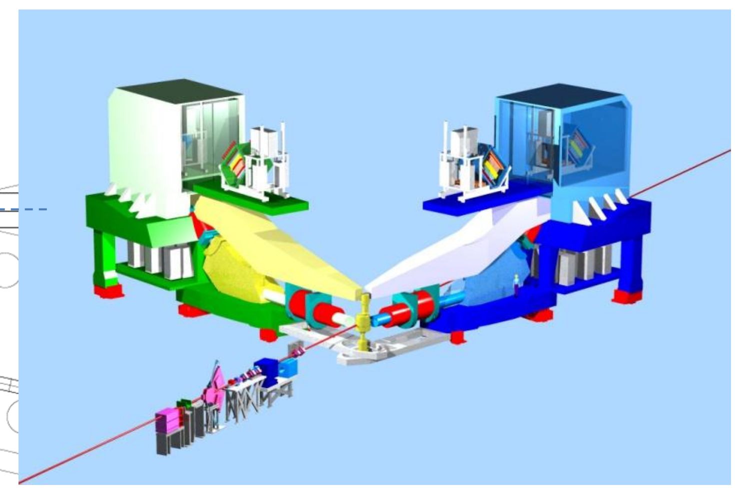
$$A = 0.656 \; ppm \pm 0.060(stat) \pm 0.014(syst)$$

→ Statistics limited (9%)

→ Systematic error goal achieved ! (2%)





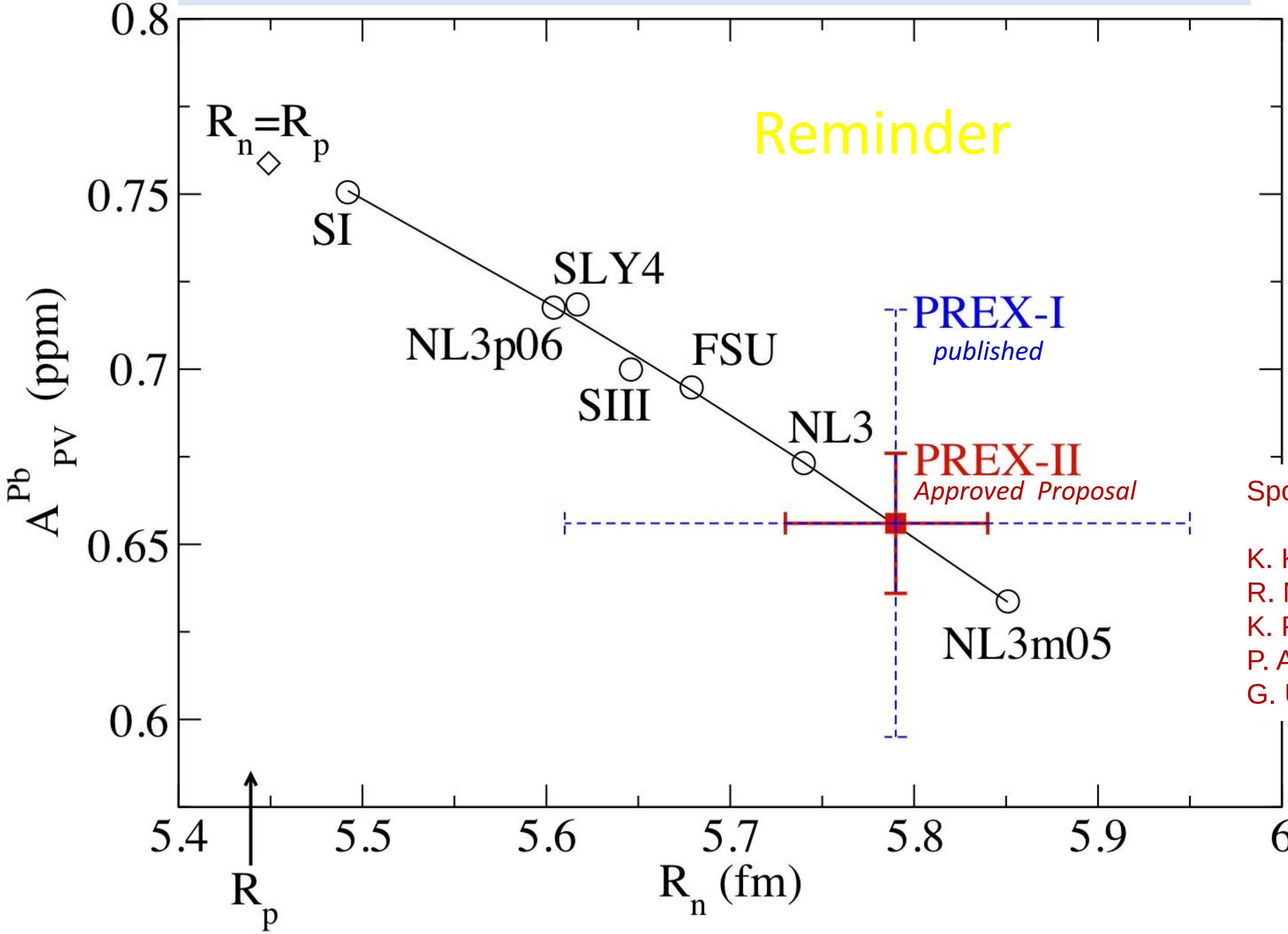


C-REX: replace ^{208}Pb with ^{48}Ca, move target back

Asymmetry leads to R_N

Establishing a neutron skin at ~95 % CL

Neutron Skin = R_N - R_P = 0.33 + 0.16 - 0.18 fm



Spokespersons

K. Kumar
R. Michaels
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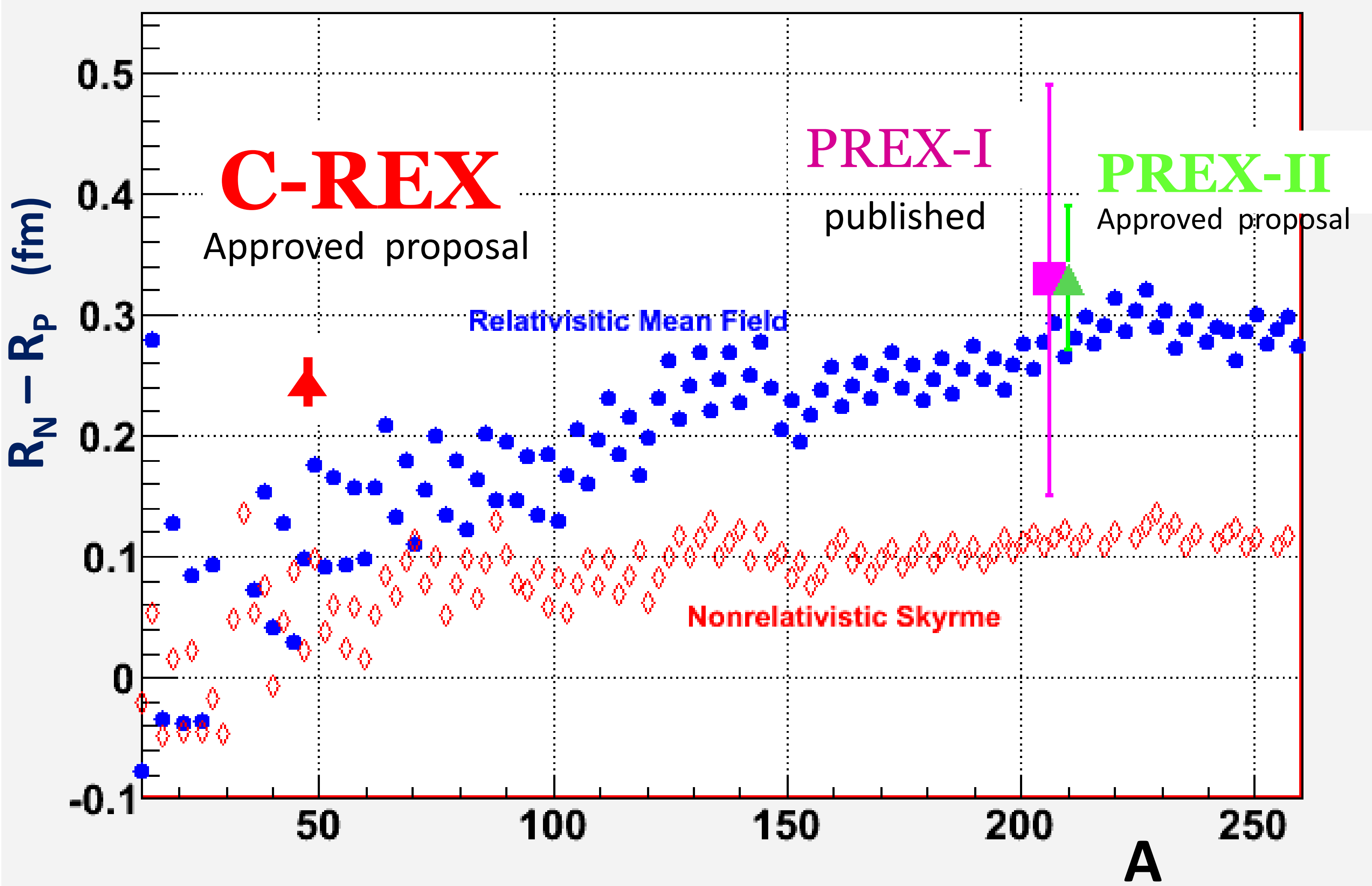
G. Urciuoli

Neutron Skin vs Mass Number A



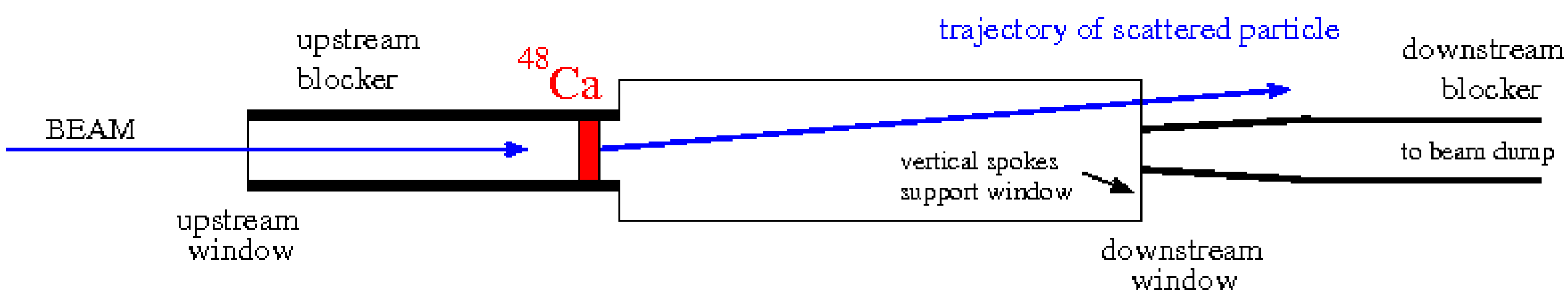
Why ^{48}Ca ? Why ^{208}Pb ? Why both ?

C-REX	PREX
➢ "Light" Nucleus ^{48}**Ca**	❖ Heavy Nucleus ^{208}**Pb**
Doubly magic, 1st excited state at 3.84 MeV → use HRS to isolate elastic	Doubly magic, 1st excited state at 2.6 MeV → use HRS to isolate elastic
relatively big neutron excess → more sensitive to R_N	44 extra neutrons, thick N skin → looks like a neutron star
"state-of-the-art" microscopic calculations now feasible → test 3N forces → bridge between ab initio and DFT theories	sensitive to dynamics of bulk neutron matter → N-stars
Smaller nucleus → higher Q^2 fits into 12 GeV program → larger Asymmetry is "easy"	The consensus first choice for parity-violating neutron density measurement.
Experimentally, want > 1 nucleus measured with this technique.	

Isotopically pure ^{48}Ca Target

- Vacuum seal to trap atoms if beam destroys target
- Higher thermal conductivity & melting point than lead : should take 150 uA.
- Similar in concept to target used in E08014 (at 40 uA)

C–REX Target Geometry



PREX/C−REX Sieve, HRS, and Septum Geometry

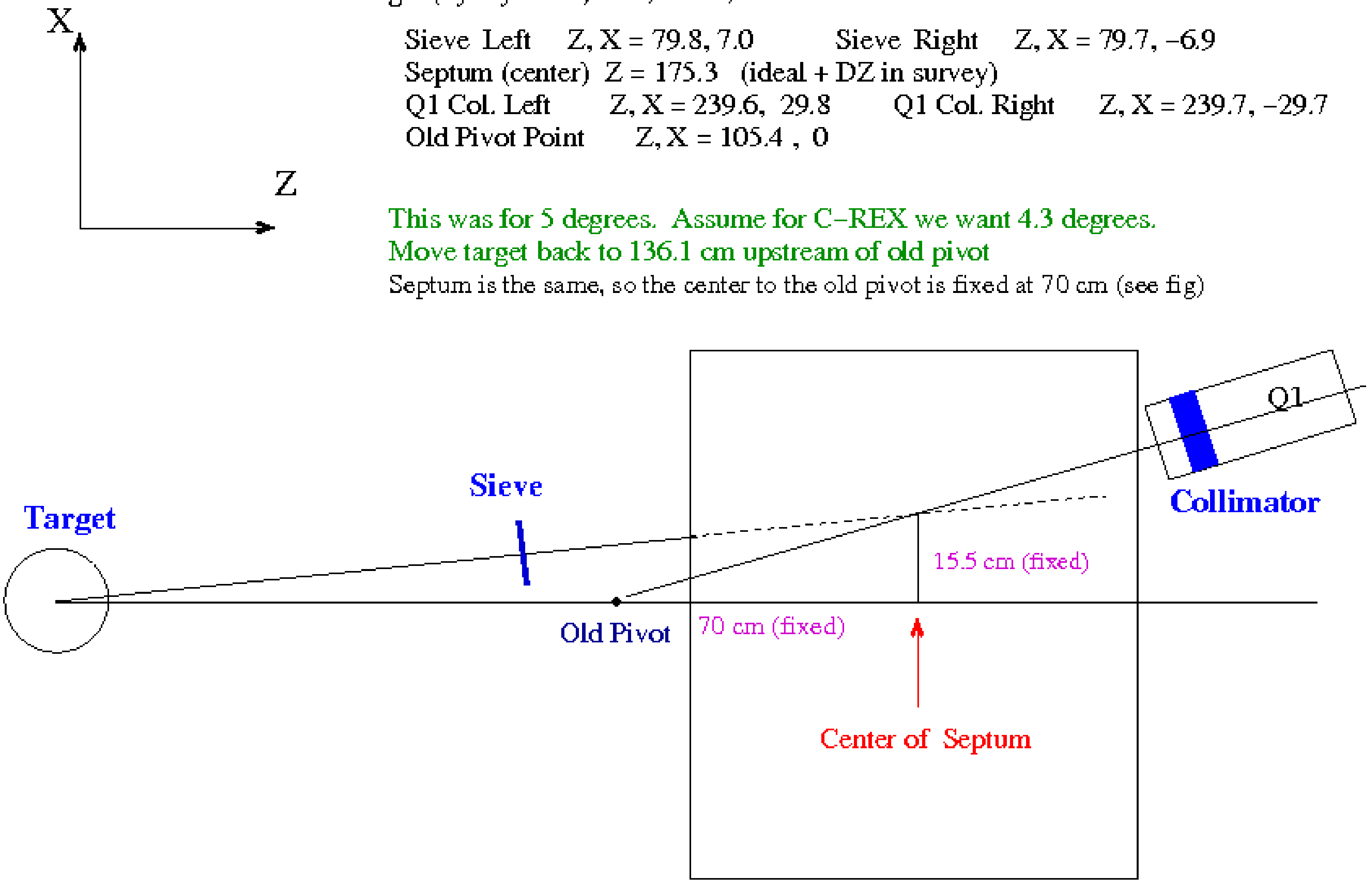
R. Michaels, Feb, 2013

Survey Data (cm)   Ref. A1277, A1279

Target (by my def'n)   Z, X = 0, 0

Sieve Left   Z, X = 79.8, 7.0   Sieve Right   Z, X = 79.7, −6.9
Septum (center) Z = 175.3 (ideal + DZ in survey)
Q1 Col. Left   Z, X = 239.6, 29.8   Q1 Col. Right   Z, X = 239.7, −29.7
Old Pivot Point   Z, X = 105.4 , 0

This was for 5 degrees. Assume for C−REX we want 4.3 degrees.
Move target back to 136.1 cm upstream of old pivot
Septum is the same, so the center to the old pivot is fixed at 70 cm (see fig)

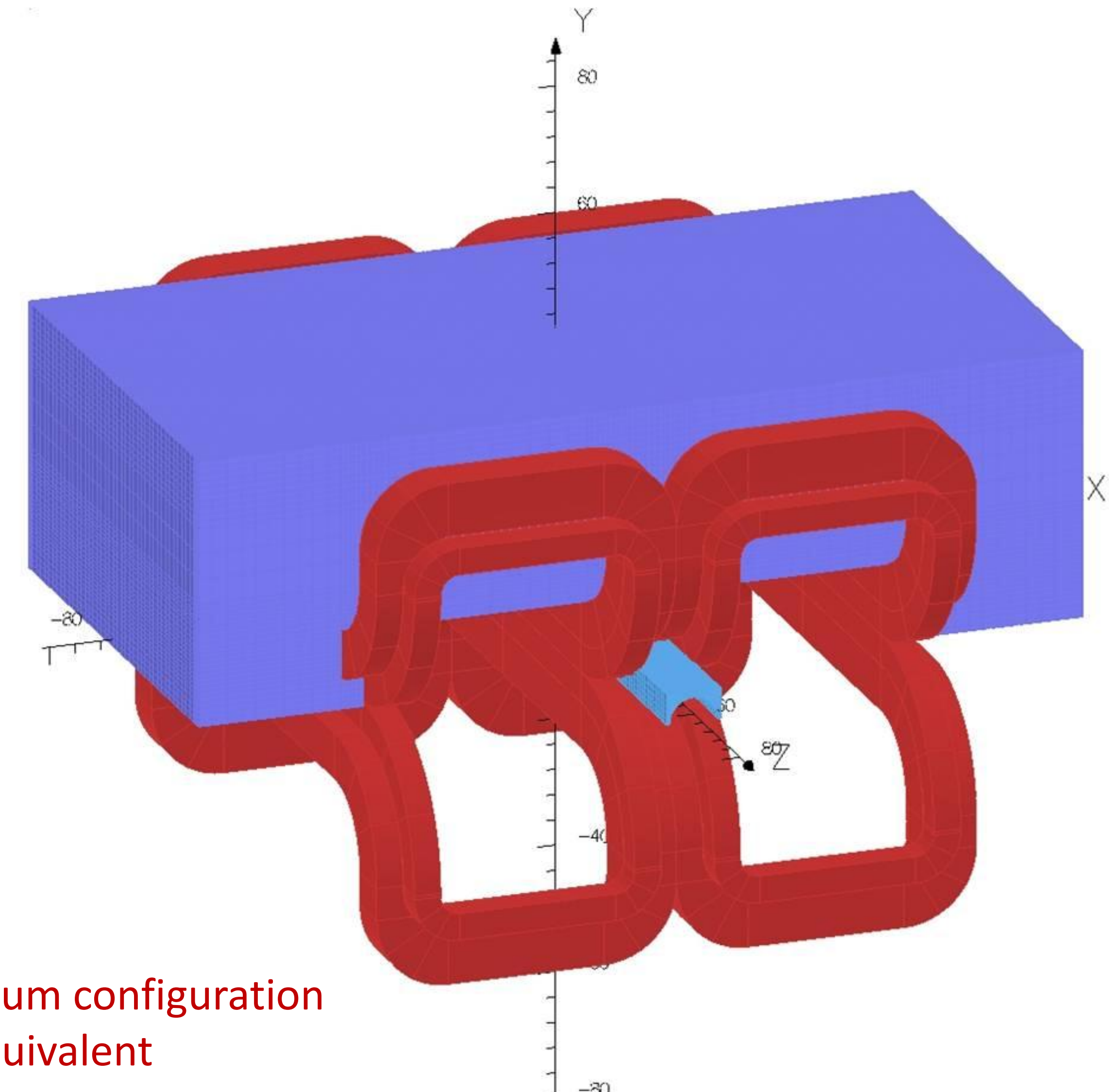


Septum Magnet

$$\theta = 4^0$$

Room temperature

Need a good dipole → hardware resolution



A 5^0 septum (ala PREX) would work, but need a non-standard energy (1.8 GeV)

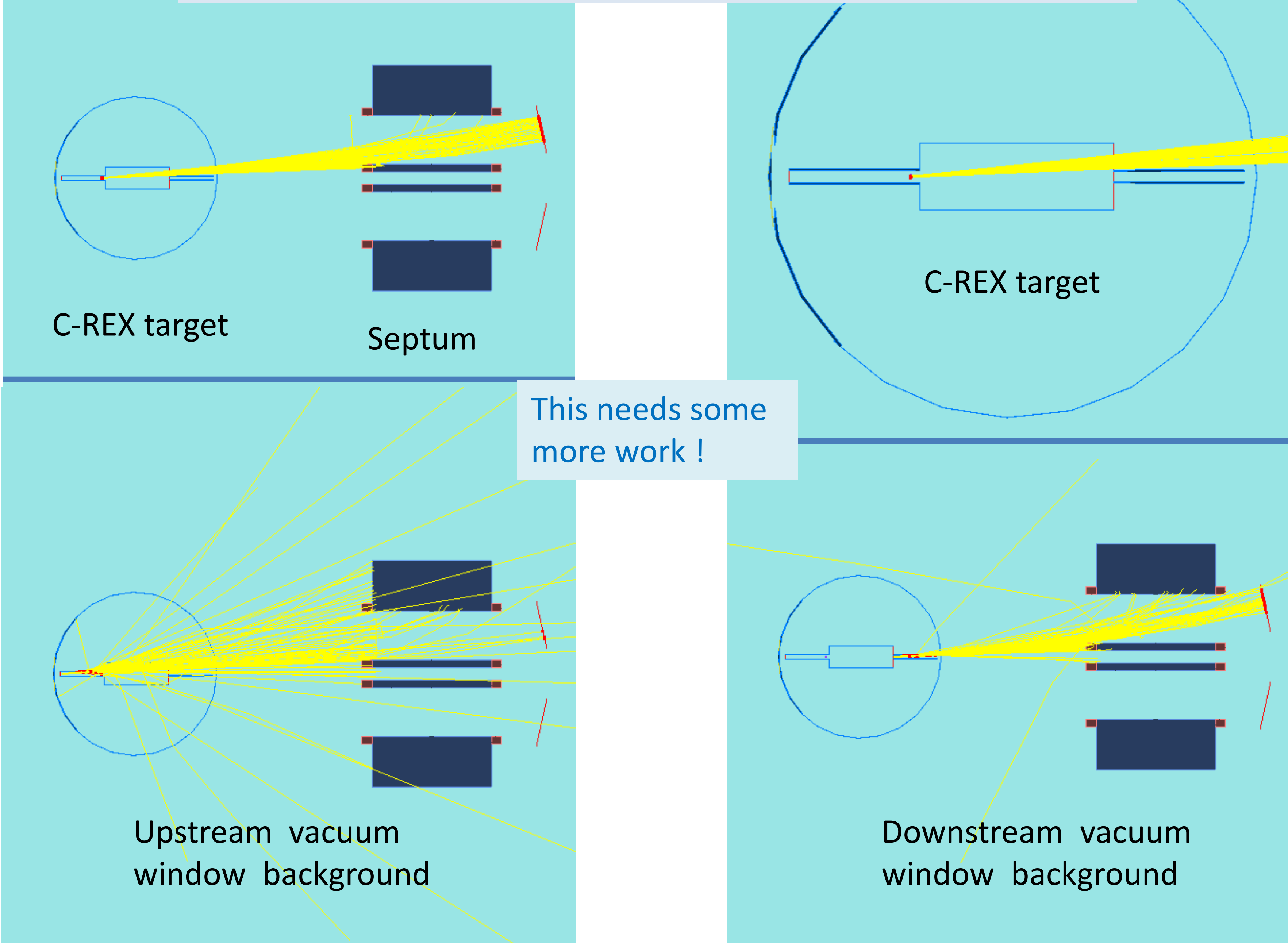
Work needs to be done to:

1. Optimize target and septum configuration
2. Check with HRSMC or equivalent

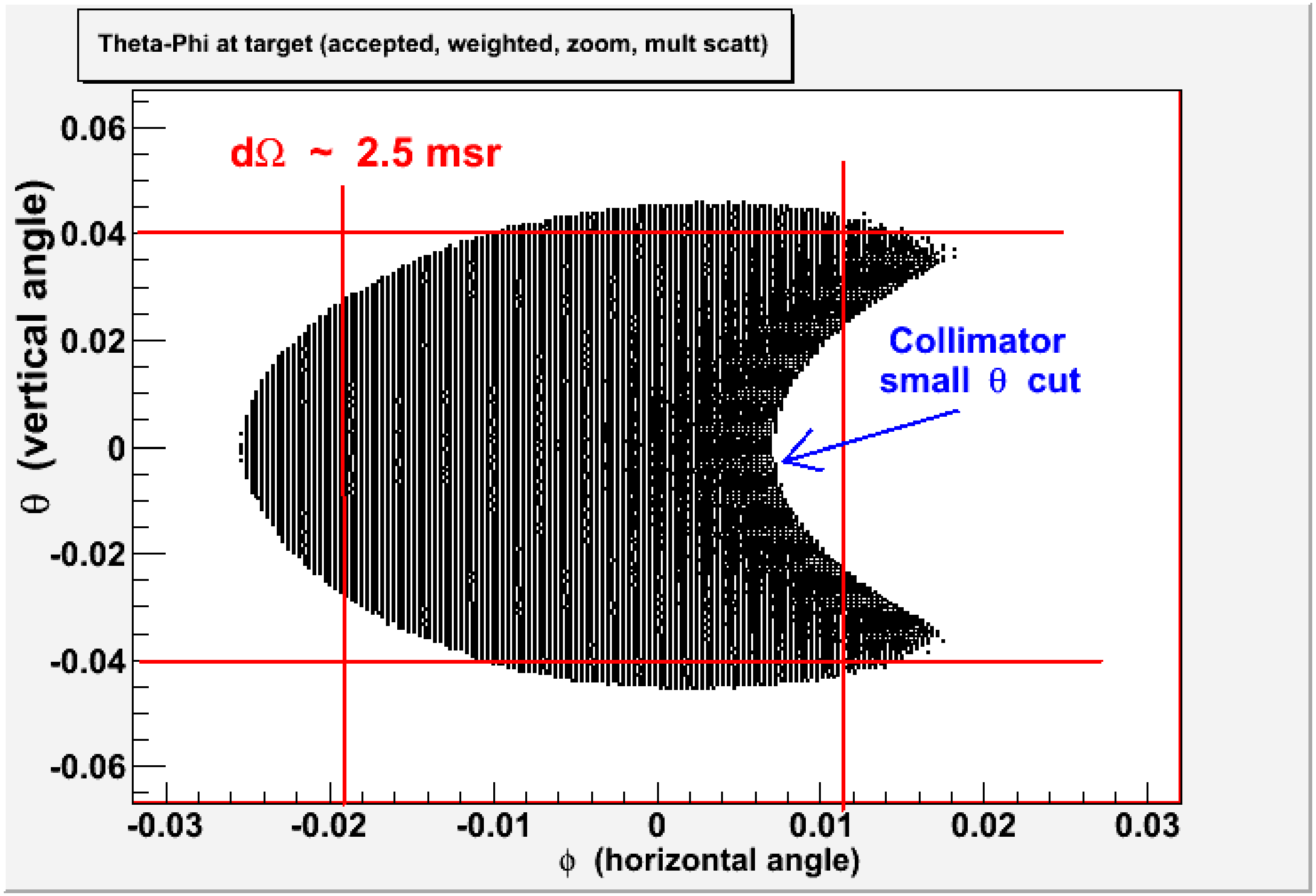
HRSMC: Geant near target + HRS transport functions

HRSMC Results

Jixie Zhang (95%) + Bob Michaels (5%)



HRS Acceptance



"hamc" Monte Carlo assumed **> 3.6 degrees**

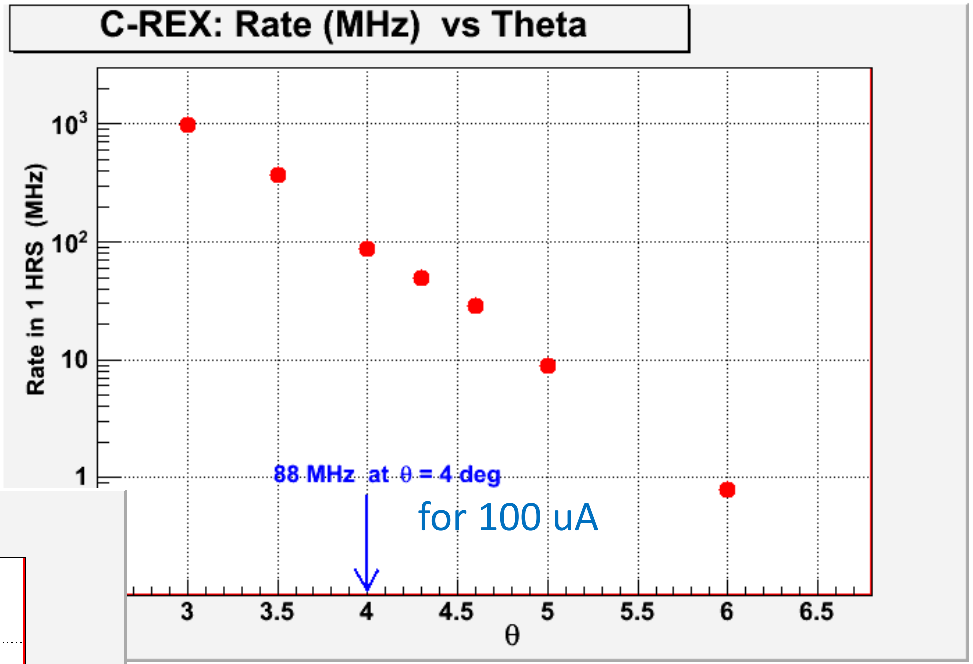
acceptance defined by collimator in Q1 entrance

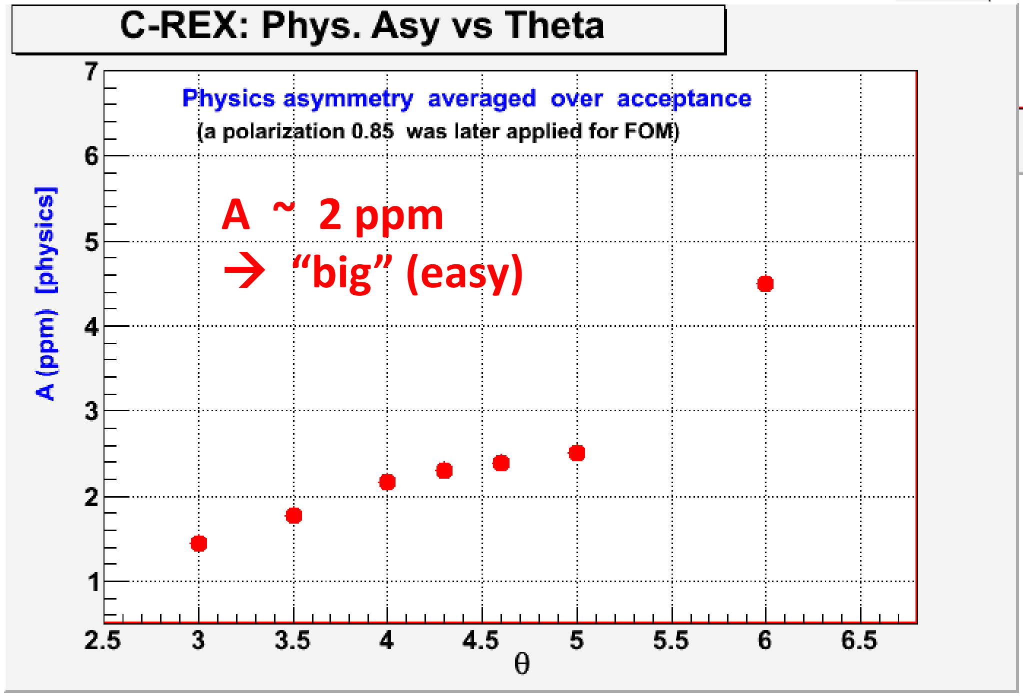
C-REX: Optimization of Kinematics (part I)

2.2 GeV
= 1-pass

$\theta = 4^0$

Rate = 88 MHz / 100uA / HRS → easy

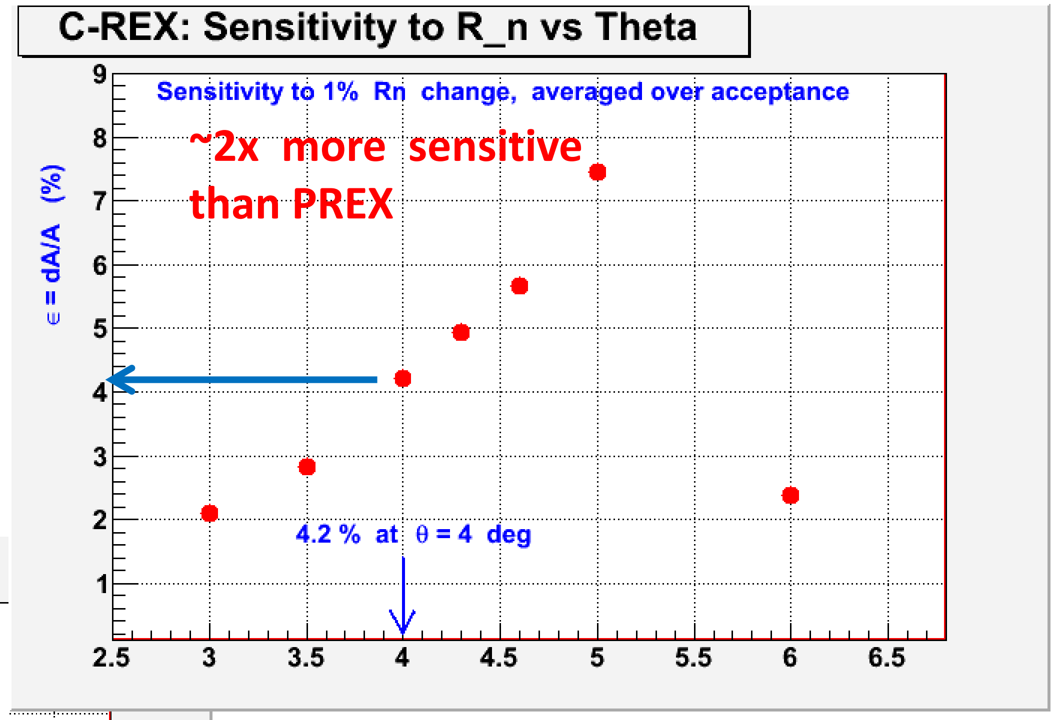


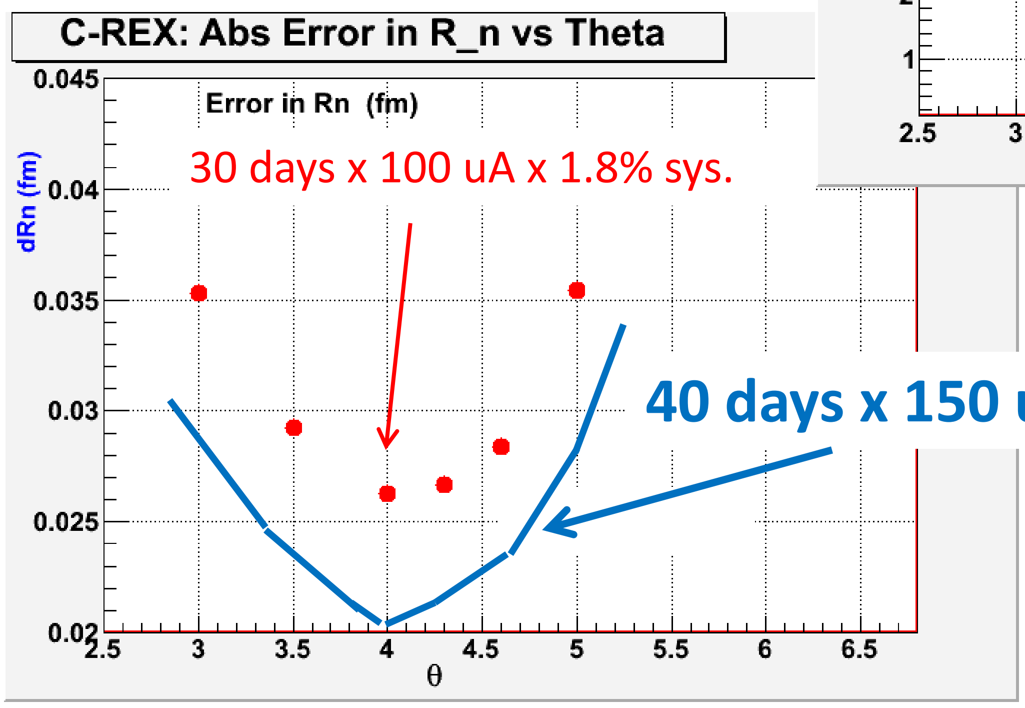


C-REX: Optimization of Kinematics (part II)

2.2 GeV
= 1-pass

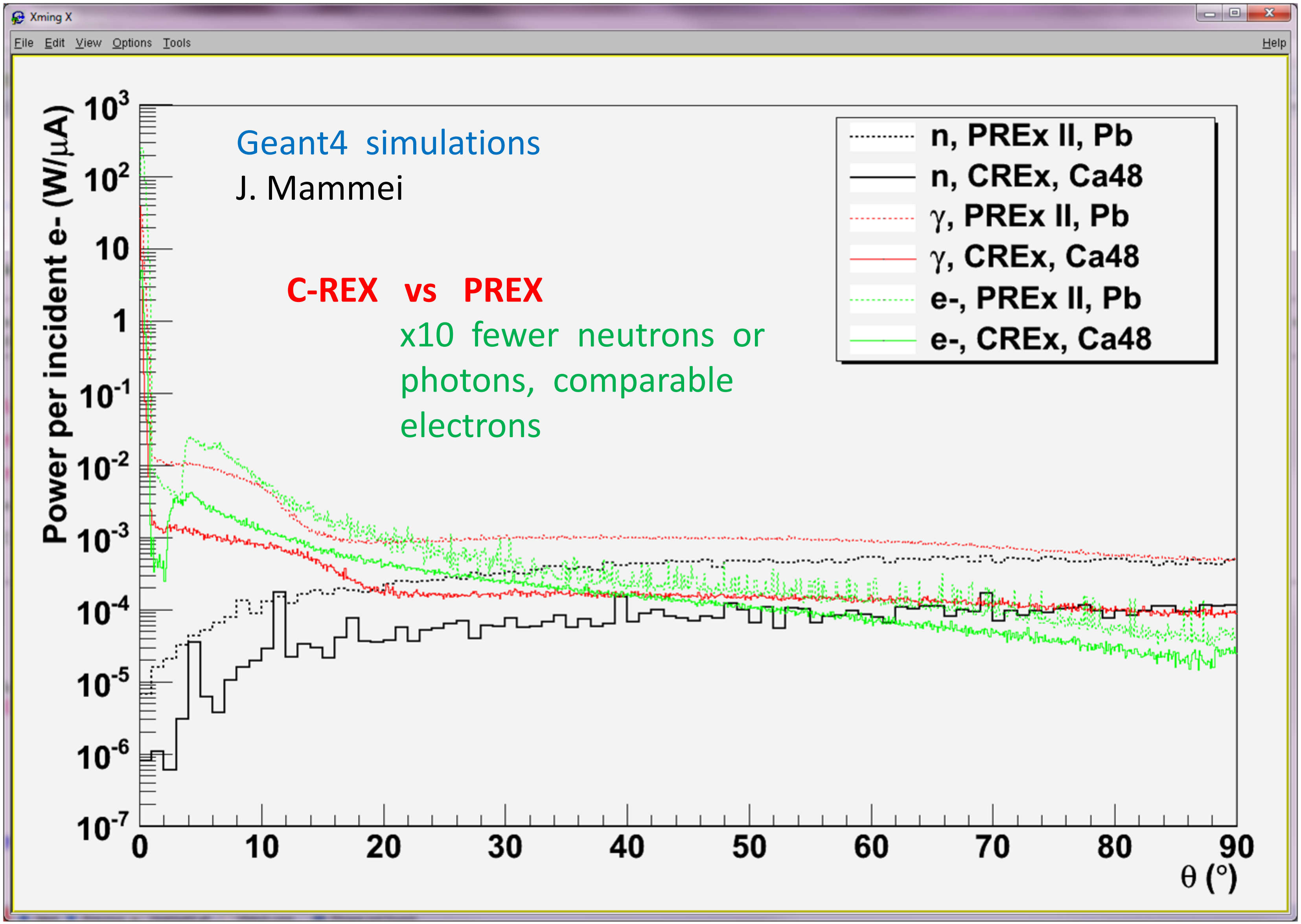
$\theta = 4^0$



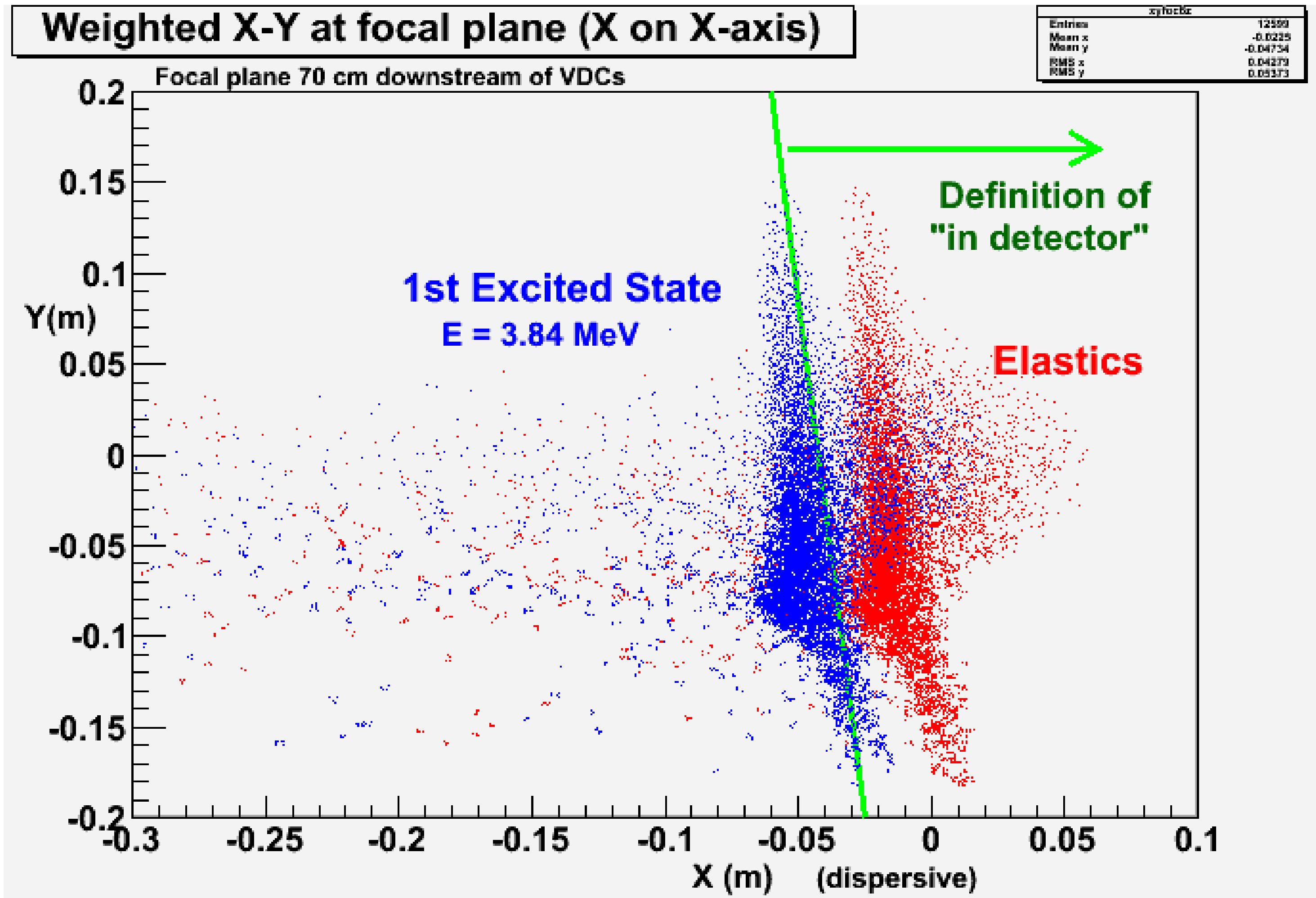


Radiation Load in Hall A

C-REX much lower than PREX



HRS Detectors -- could be optimized



C-REX To-Do List

- Optimize the target and septum region
- Build and test the target.
- Pick the best septum strategy
- Setup and alignment procedure
- Finalize Detector design
- Radiation shielding is easier than PREX
- Run strategy ? (run with PREX-II ?)
- Polarimetry is demanding

Fini !