Overview of PREX/CREX Experiments

May 17, 2017

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Introduction

This presentation: Introduction and overview of the PREX/CREX experimental design to orient those who are unfamiliar and highlight important features.

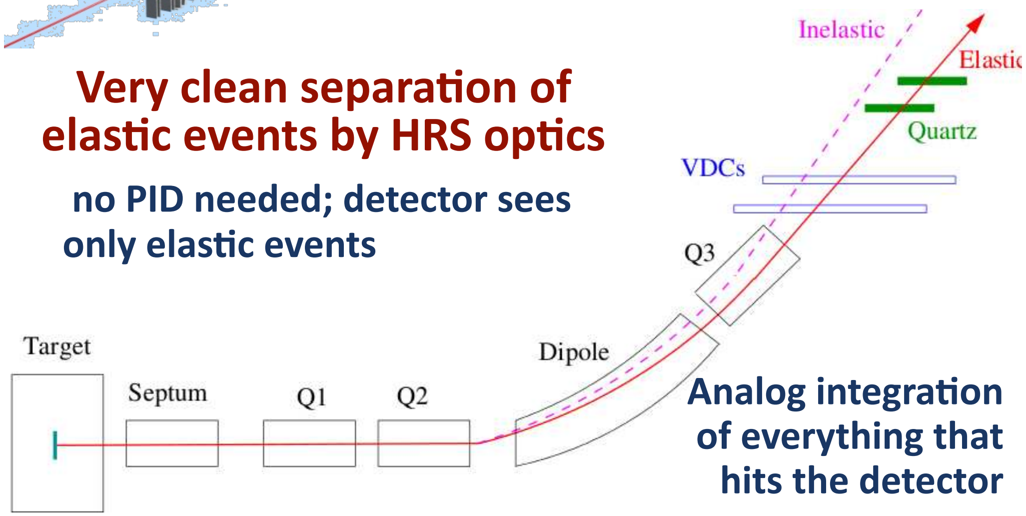
Next presentation: Seamus will summarize answers to the 2016 ERR recommendations.

Introduction to PREX-II/CREX
Change in CREX kinematics to simplify design
Developments since 2016 ERR
- running the septum
- scattering chamber design
Review of essential equipment

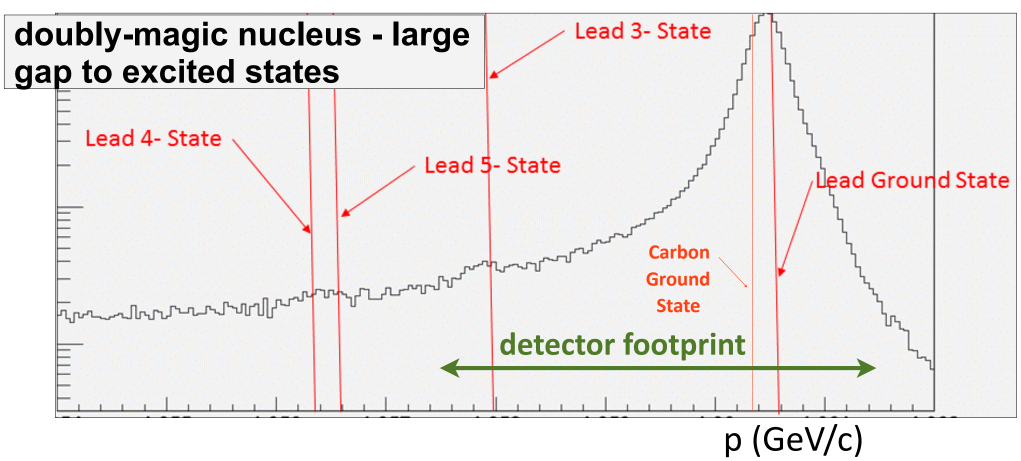
PREX in Hall A

Very clean separation of elastic events by HRS optics

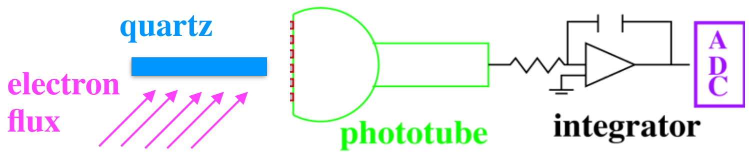
no PID needed; detector sees only elastic events

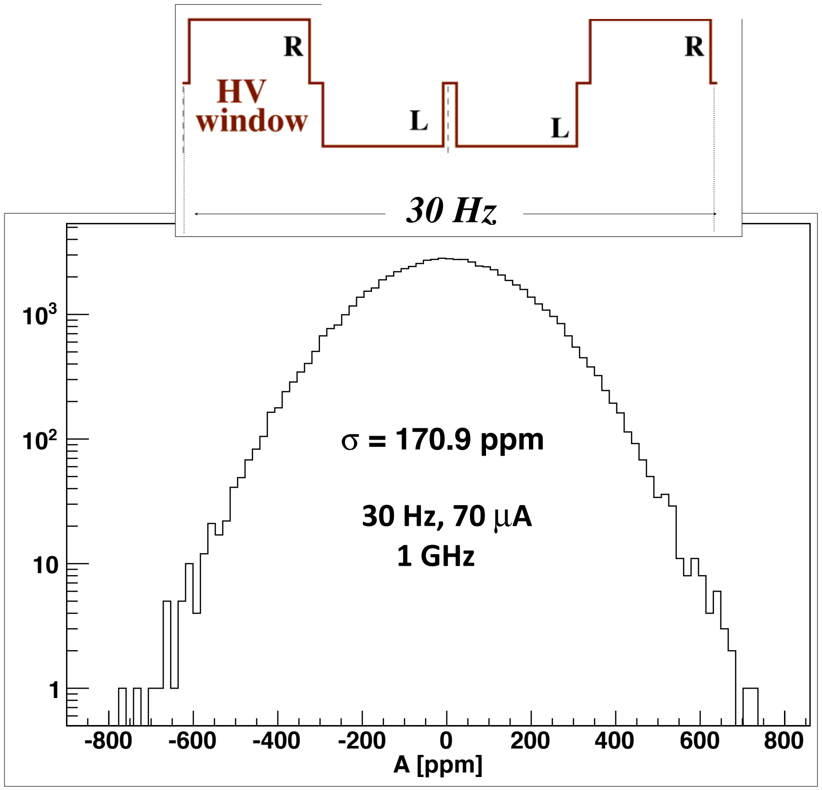


Analog integration of everything that hits the detector



Flux integration Technique





CREX: 50 MHz

HAPPEX-II: 100 MHz

PREX: 1 GHz

Qweak: 5 GHz

PREX/CREX Summary

PREX-2: 25+10 days, 3% stat, 0.06 fm
CREX: 35+10 days, 2% stat, 0.02fm

Achieved

PREX-I

E=1.1 GeV, 5°
A=0.6 ppm

Charge Normalization	0.2%
Beam Asymmetries	1.1%
Detector Non-linearity	1.2%
Transverse Asym	0.2%
Polarization	1.3%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.5%
Total Systematic	**2.1%**
Total Statistical	**9%**

PREX-II

E=1.1 GeV, 5°
A=0.6 ppm

Charge Normalization	0.1%
Beam Asymmetries*	1.1%
Detector Non-linearity*	1.0%
Transverse Asym	0.2%
Polarization*	1.1%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.4%
Total Systematic	**2%**
Total Statistical	**3%**

CREX

E=1.9 GeV, 5°
A = 2.28 ppm

Charge Normalization	0.1%
Beam Asymmetries	0.3%
Detector Non-linearity	0.3%
Transverse Asym	0.1%
Polarization	0.8%
Target Contamination	0.2%
Inelastic Contribution	0.2%
Effective Q^2	0.8%
Total Systematic	**1.2%**
Total Statistical	**2.4%**

Total charge on target (includes commisioning):

82 C

Proposed charge on target (includes commissioning):

170 C

*Experience suggests that leading systematic errors can be improved beyond proposal

What We Learned in PREX-I

What Worked:

New Septum
We now know how to tune it to optimize FOM

HRS Tune
We have a tune and good first-guess optics matrix for a tune optimized for the small detectors

Polarimetry at low energy
High-field Moller at 1.3%,
Integrating Compton at 1.2%

New Integrating Detectors
Suitable energy resolution achieved for 1 GeV electrons. <5% precision loss.

Lead Target
Survival >25 C

Fast Helicity Flipping
We know how to control false asymmetries and monitor performance

Injector Spin Manipulation
Second Wein and solenoid are calibrated and used for helicity reversal. Important cancellation for systematic beam asymmetries from the polarized source.

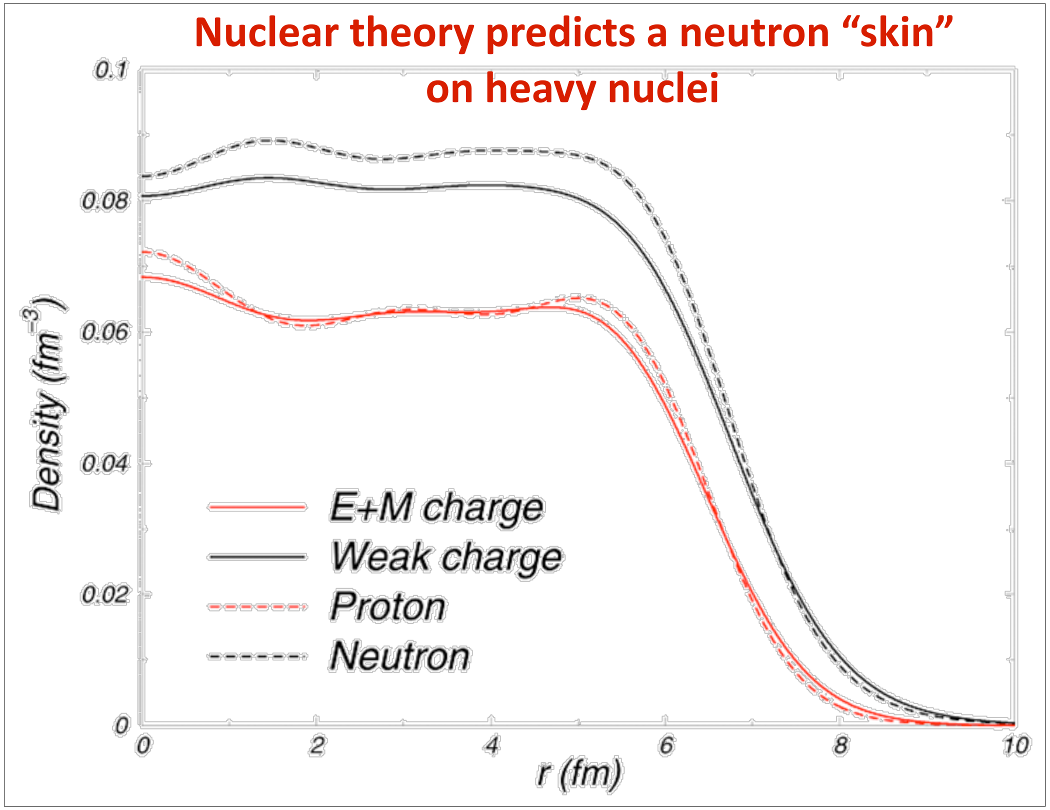
Beam Modulation System
Fast beam kicks cancel low frequency noise and improve precision of beam position corrections

A_T false asymmetry
A_T is small (<1 ppm Pb, <10 ppm C) and A_{false} will be small if P_T is minimized

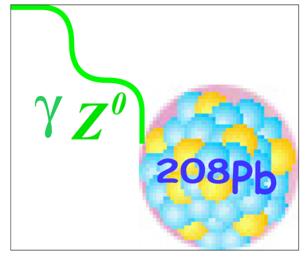
In terms of statistical power and systematic control, PREX-I worked

- PREX-I has >200 citations on inspirehep, strong support for PREX-II

Weak Charge Distribution of Heavy Nuclei

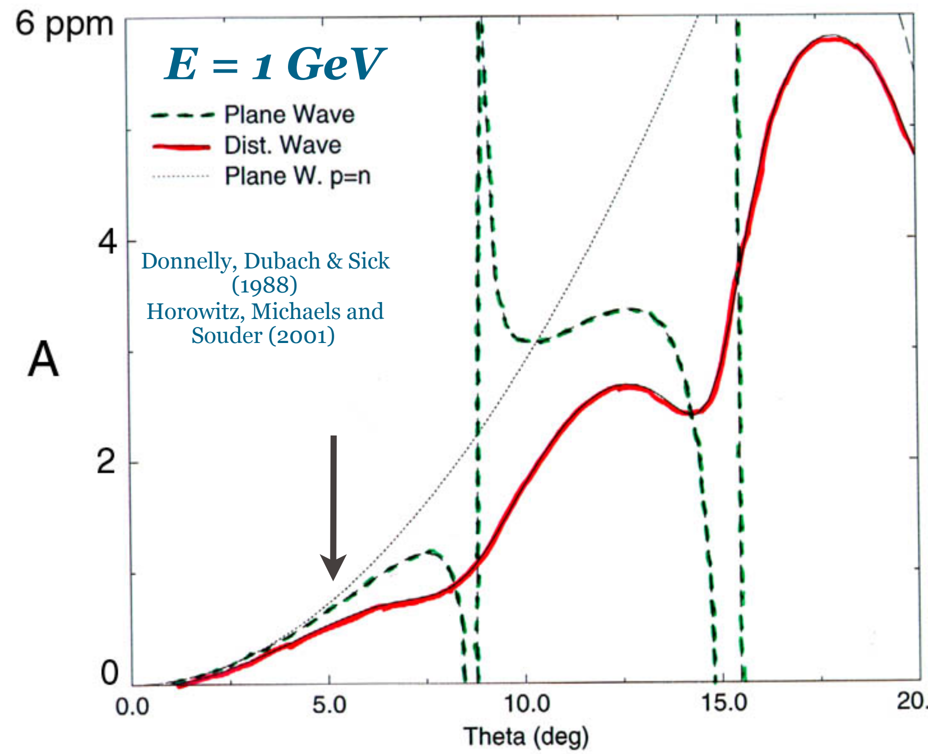


	proton	neutron
Electric charge	1	0
Weak charge	~0.08	1



for spin-0 nucleus

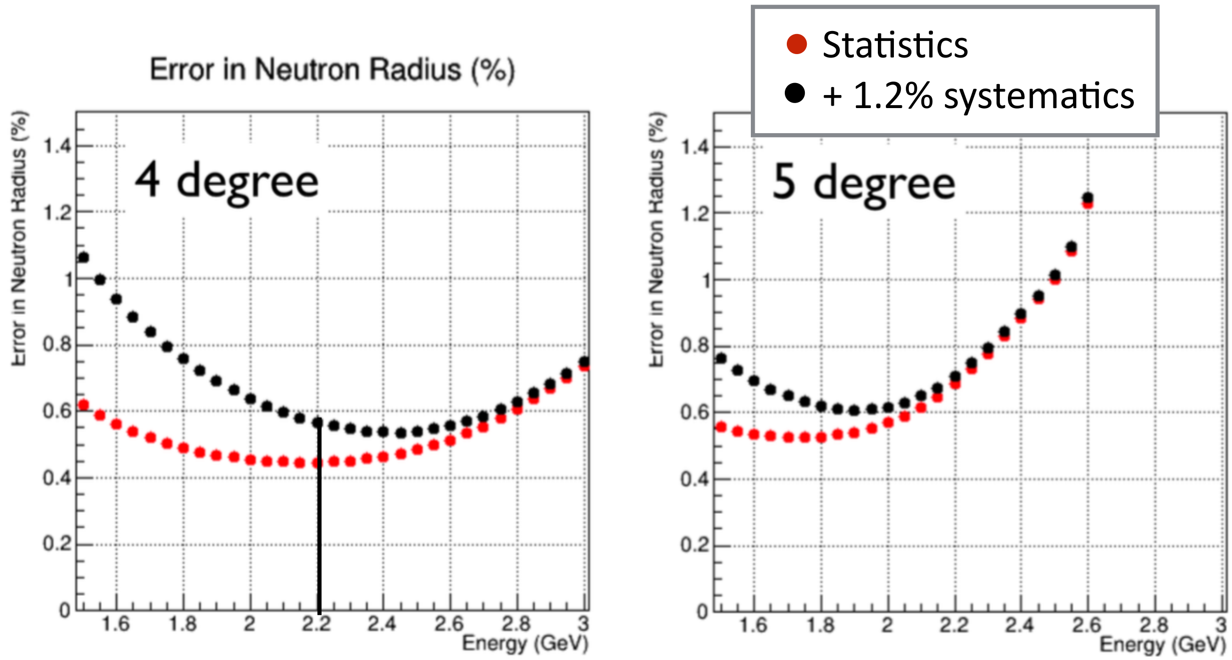
$$A_{\rm PV} \approx \frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \frac{F_W}{F_{ch}}$$



Really measuring how F_W is different than F_{ch}. Sensitivity is found by approaching the diffractive minimum for F_{ch}, but maintaining enough rate for precise measure of A_{PV}

CREX at 5 degrees

CREX at 5° scattering angle maintains figure-of-merit



Precision on A_{PV} goes down, but sensitivity to R_n gets better

Many benefits:

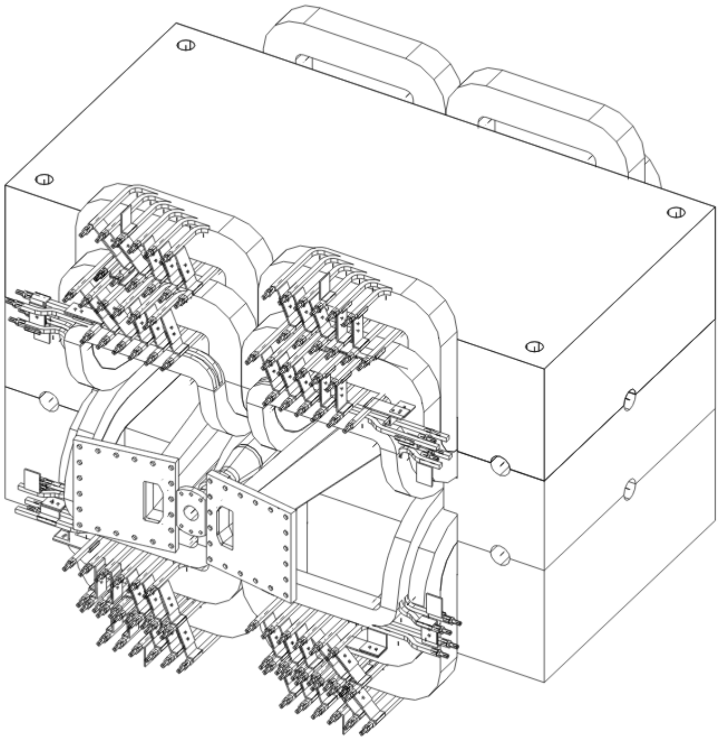
- single production target location
- reduced bend in septum
- more statistics dominated
- E_{beam} <2.2 GeV
- Reduced radiation level

angle	energy	rate [MHz]	A_{PV} [ppm]	$\delta A/A$ (stat) [%]	$\delta R/R$ (total) [%]
4°	2.0 GeV	440	1.86	1.3	0.64
4°	2.1 GeV	310	2.0	1.4	0.60
4°	**2.2 GeV**	**220**	**2.1**	**1.6**	**0.57**
5°	1.8 GeV	130	2.16	2.0	0.62
5°	**1.9 GeV**	**79**	**2.28**	**2.4**	**0.61**
5°	2.0 GeV	48	2.37	3.0	0.62
5°	2.1 GeV	28	2.44	3.8	0.65
5°	2.2 GeV	16	2.49	4.9	0.71

Septum

3 coils, shims (g2p configuration) will be used to comfortably achieve CREX requirement

	PREX	CREX-5^o	CREX-5^o	g2p (May 17, '12)
Beam Energy [GeV]	1.068	1.9	2.2	3.0
Current [A]	377	718	805	1050



PREX/ CREX: 7.5^o bend angle, p_0=1.07 GeV, 2.2 GeV
g2p: 6.8^o bend angle, as high as p_0=3 GeV

Acceptance with shims already folded into FOM estimates

See talk by Juliette Mammei

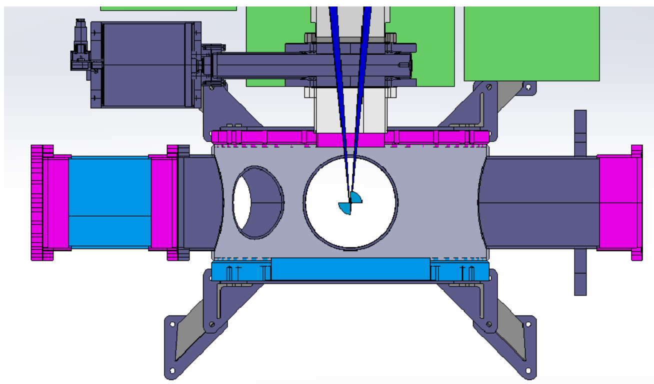
Scattering Chamber Design

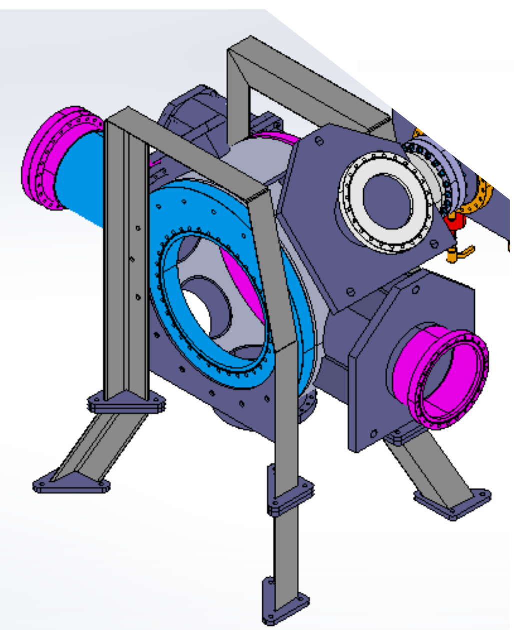
Design driven by Silviu Covrig Dusa

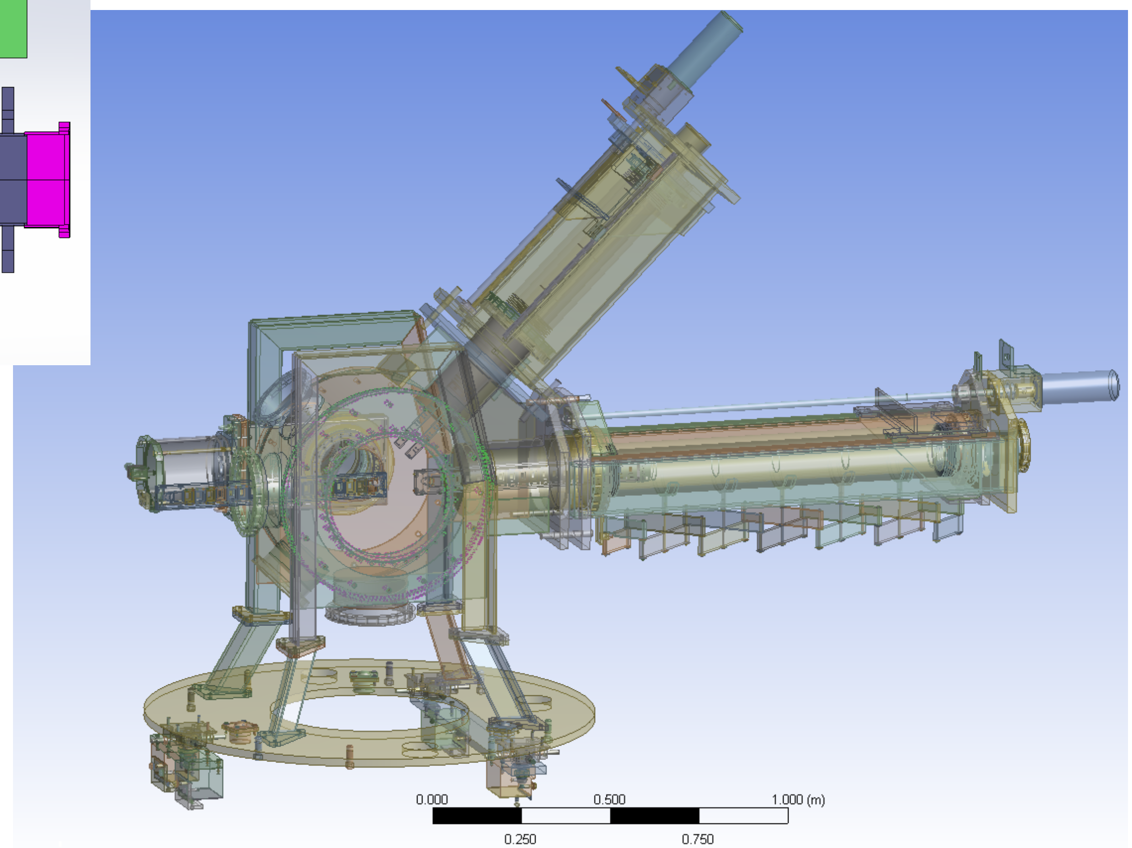
Long stroke for production target, separate warm arm for optics (watercell)

Design incorporates plans for alignment, installation, Ca target protection

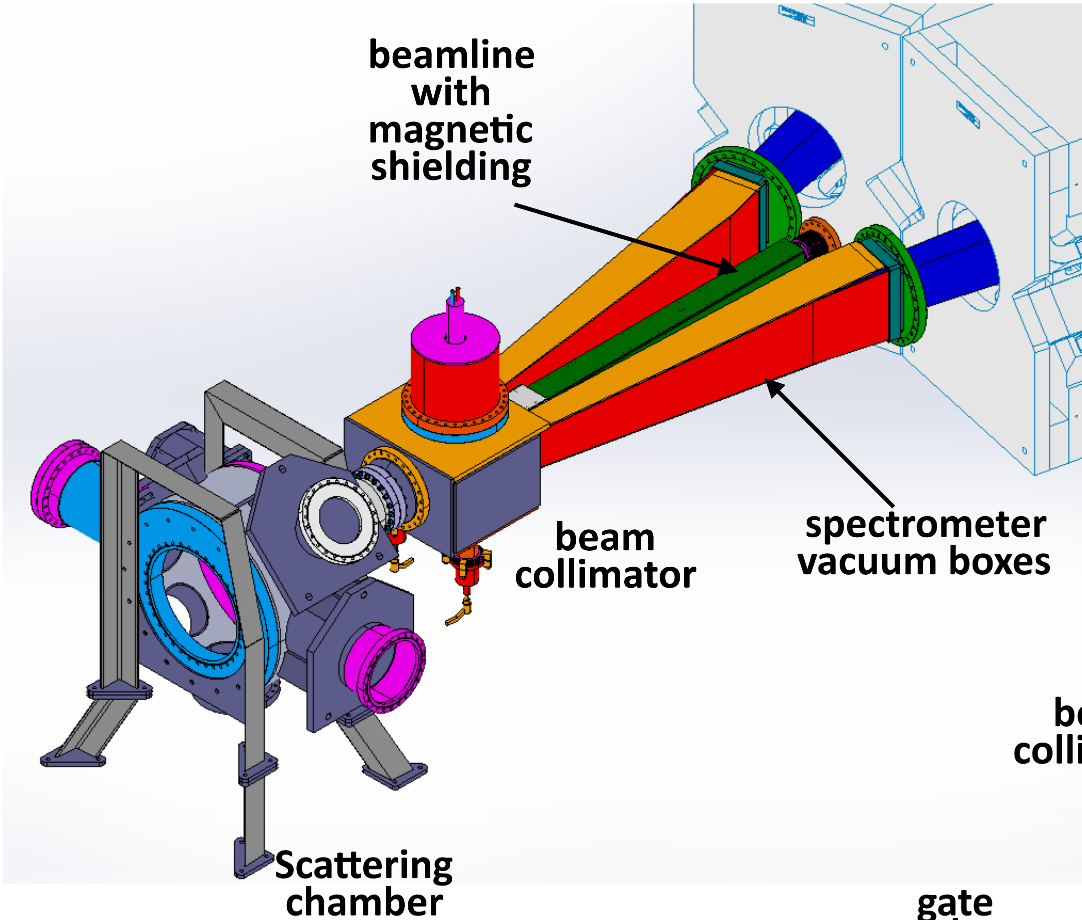
Includes designs of movers and cryo plumbing, to be finalized by target group



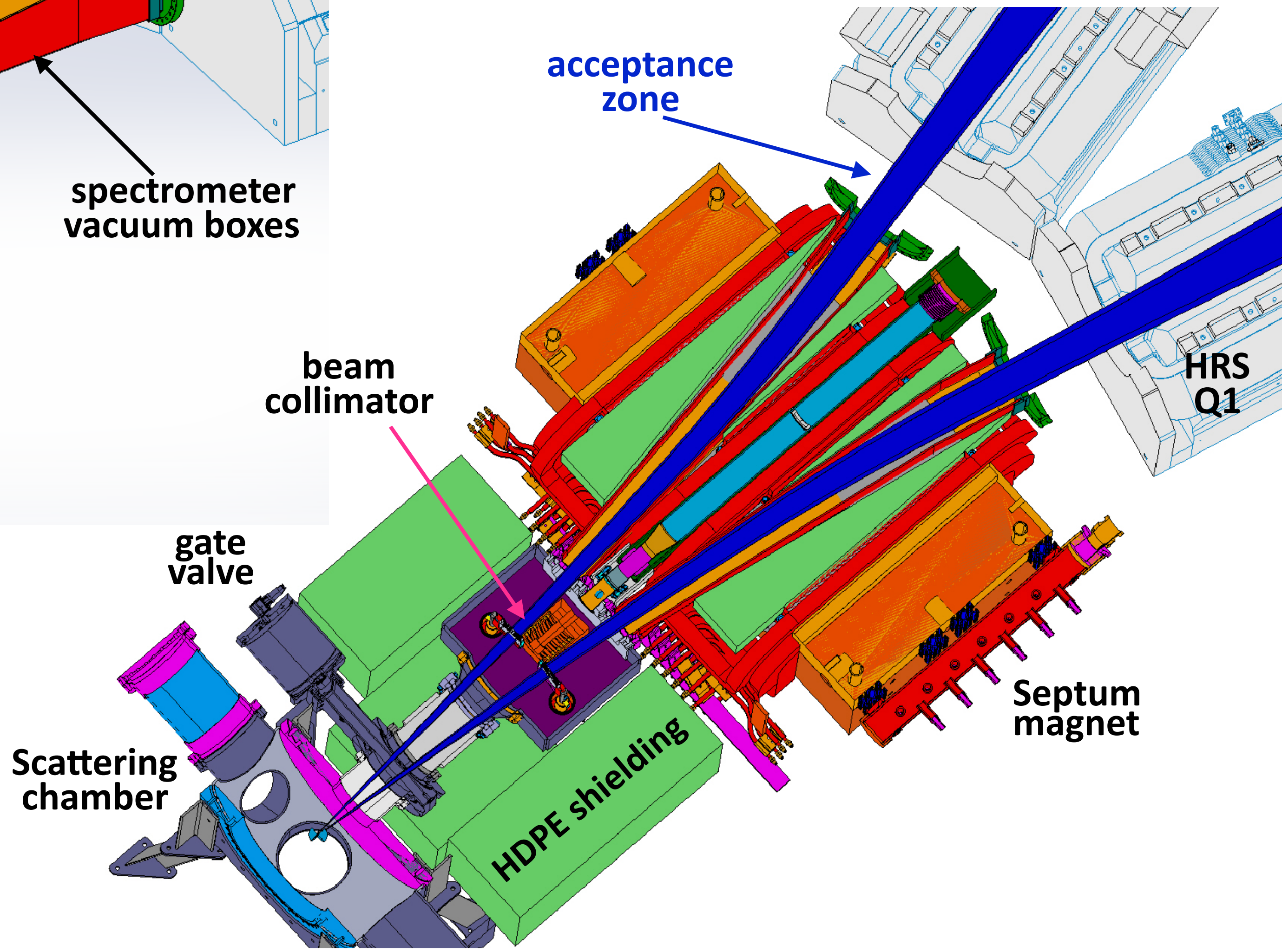




Pivot Region



Design Document
Specifies a reference design to communicate experimental needs to design and engineering



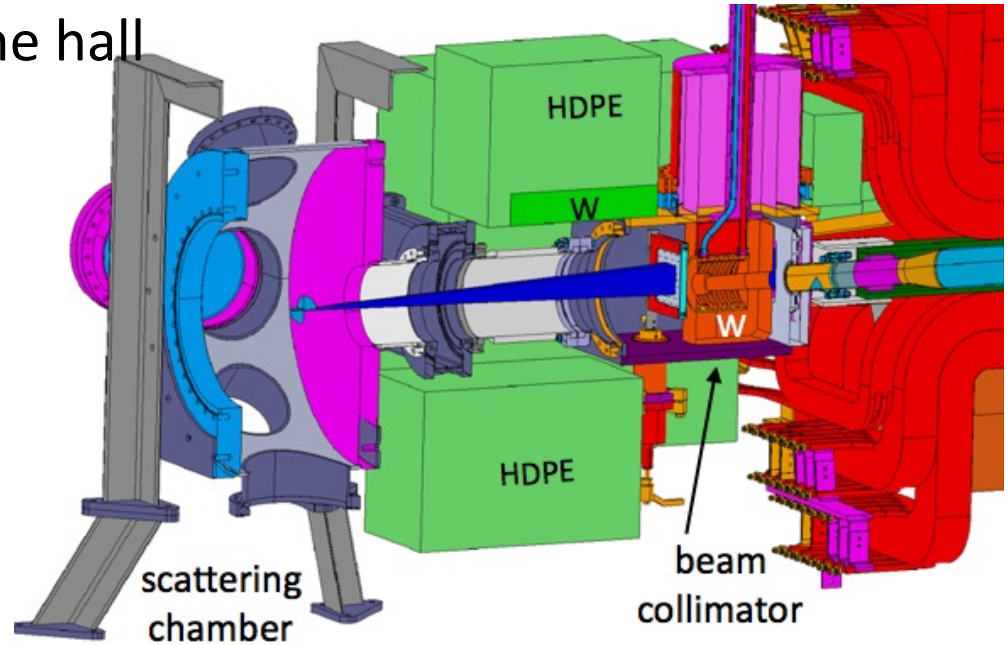
Radiation

PREX-I distributed significant power into the hall

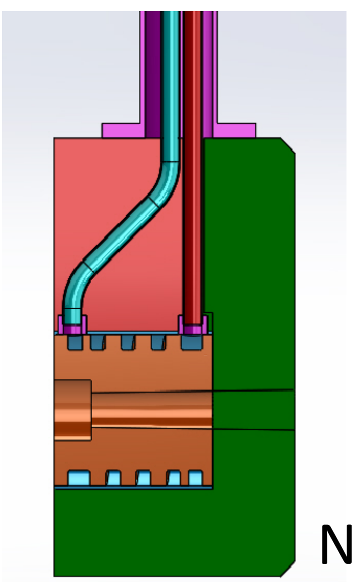
- heavy target, low energy

Solution:

Localize power in hall at collimator, and shield it well



	PREX-I	PREX-II	CREX
Power in collimator (W/μA)	9.7	28.6	5.2
Power in hall (W/μA)	18.0	3.4	0.6



Total 1 MeV neutron-equivalent dose [$10^9/cm^2$]

HRS power supplies	PREX II	CREX	PVDIS	PREX-I
electron	14	21	16	125
neutron	8	15	10	105
total	**21**	**36**	**26**	**230**

See presentation on radiation

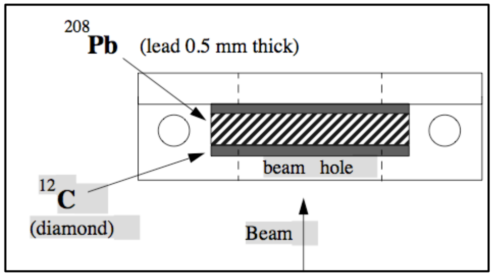
New issue: magnetic shielding on beamline through Q1's is required

Other Aspects on the Path to High Precision

- High luminosity lead and calcium target
- Beam
- Optics calibration
- Integrating detector
- Polarimetry
- Planning and organization

Lead / Diamond Target

Lead has low melting point, and low thermal conductivity
Diamond foils have excellent thermal conductivity
^{12}C is isoscalar, spin-0: benign background
Use synchronized raster to handle non-uniform lead thickness



Well tested! PREX-I with 3 targets measured average lifetime >27 C

PREX-I suggests <6 targets are needed for full PREX-II luminosity, so 10 targets on ladder is a large margin of safety

Calcium Target

Thinner than proposal.
- *Tilt the foil to recover thickness*

Oxidized surface
- Expected *contaminants (O, N, C, H) are not dangerous background - we don't need tight limit on surface layer*
- *Scraping surface should sufficiently eliminate contaminants*

See Talk by Seamus Riordan

Beam

Recent test runs to check beam quality, monitor performance

BCM resolution exceeds PREX requirements

PREX-II statistical width ~ 120ppm @ 30Hz

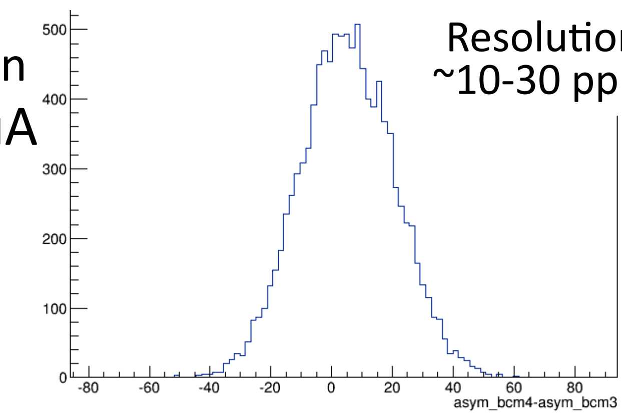
BCM resolution of 40ppm would be 5% loss of resolution

1 MHz BCM electronics: ~25 ppm resolution @ 30 Hz, 20uA

Confirmed by excess noise with small-angle detectors

Similar to width measured in PREX-I

"double-difference" width

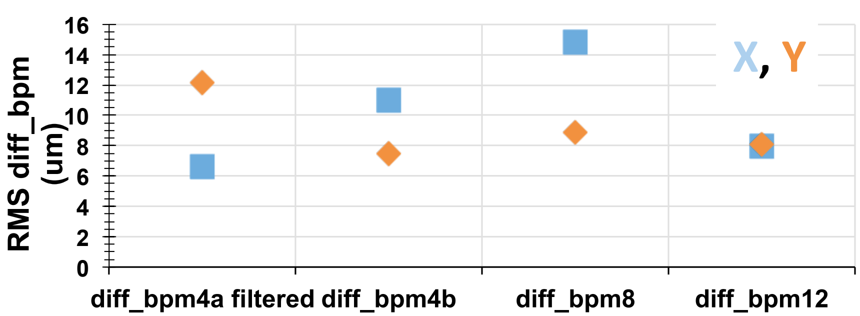


Charge and position jitter looks similar to 6 GeV era

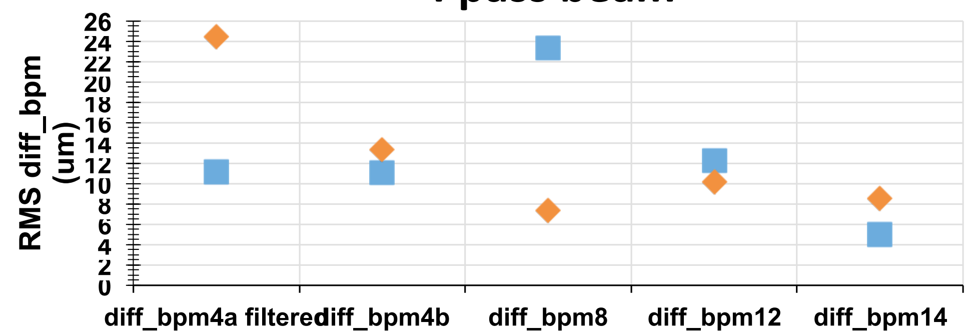
A_Q: 100-300 ppm RMS. Δx: 5-25 um RMS. (20 μA, 30 Hz, 2.2 GeV)

Including "full gradient", 2.2 GeV at 1 pass

1 pass beam



4 pass beam



PQB

See talk by Yves Roblin

source optimization, slow reversals, matching, diagnostics, polarimetry

All requirements met before, machine capabilities remain as before

CEBAF Parity Violation Experiments

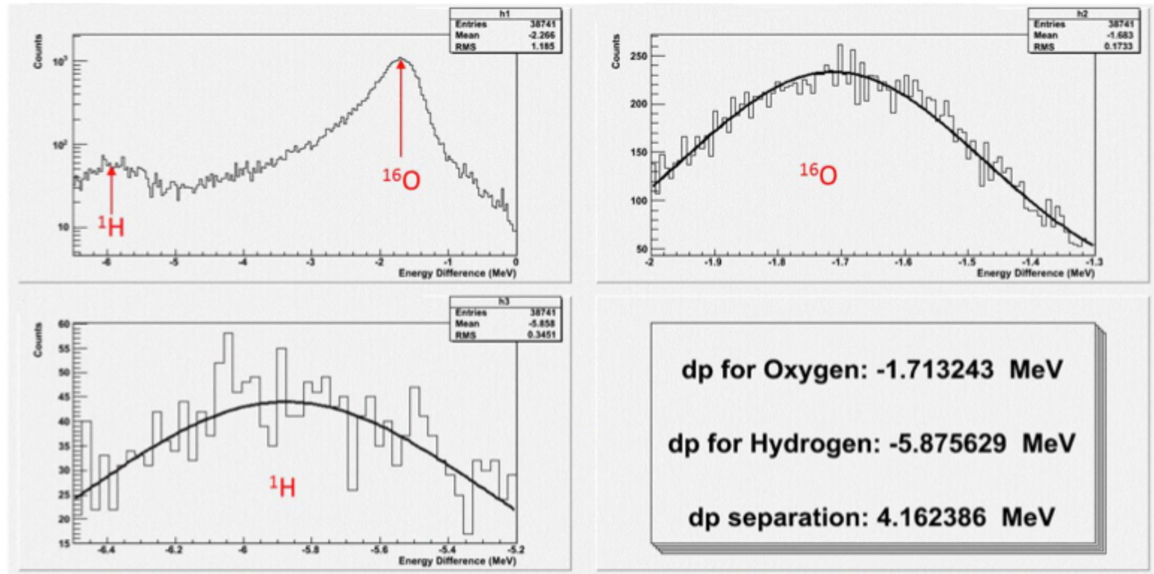
Experiment	Energy (GeV)	Pol (%)	I (μA)	Target	A_{PV} Expected (ppb)	Charge Asym (ppb)	Position Diff (nm)	Angle Diff (nrad)	Size Diff ($\delta\sigma/\sigma$)
HAPPEx-I (Achieved)	3.3	38.8 68.8	100 40	^{1}H (15 cm)	15,050	200	12	3	
G0-Forward (Achieved)	3	73.7	40	^{1}H (20 cm)	3,000-40,000	300±300	7±4	3±1	
HAPPEx-II (Achieved)	3	87.1	55	^{1}H (20 cm)	1,580	400	2	0.2	
HAPPEx-III (Achieved)	3.484	89.4	100	^{1}H (25 cm)	23,800	200±10	3	0.5±0.1	
PREx-I (Achieved)	1.056	89.2	70	^{208}Pb (0.5 mm)	657±60	85±1	4	1	
QWeak-I (Achieved)	1.155	89	180	^{1}H (35 cm)	281±46	8±15	5±1	0.1±0.02	
QWeak (Analysis In Progress)	1.162	90	180	^{1}H (35 cm)	234±5	<100±10	<2±1	<30±3	$<10^{-4}$
PREx-II (To Be Scheduled, FY18?)	1	90	70	^{208}Pb (0.5mm)	500±15	<100±10	<1±1	<0.3±0.1	$<10^{-4}$
MØLLER (To Be Scheduled, FY21+?)	11	90	85	^{1}H (150 cm)	35.6±0.74	<10±10	<0.5±0.5	<0.05±0.05	$<10^{-4}$

- PREx-II and its cousin, CREx, have requirements similar to QWeak-I. CEBAF can support these experiments without modification.
- Møller PQB requirements order of magnitude more stringent than previous parity experiments.

HRS and Kinematics Calibration

“New” HRS (SOS quad)

- Acceptance limited by septum, not Q1



Tracking Analysis

- Low current to keep rates low
- Tracking with standard VDC package
- Must verify no rate effects - GEMs would remove this potential uncertainty

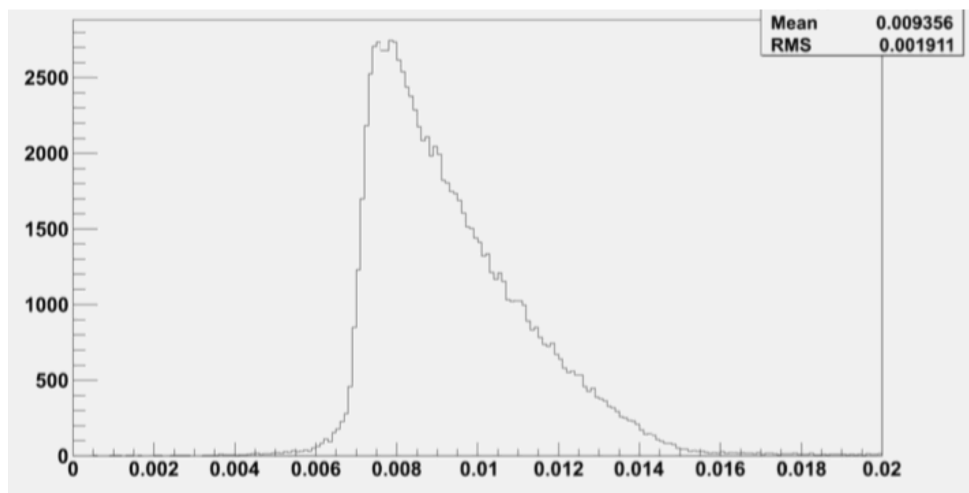
Pointing Calibration

Water Cell

- H peak on O radiative tail
- separation gives precision angle determination (~0.5%)

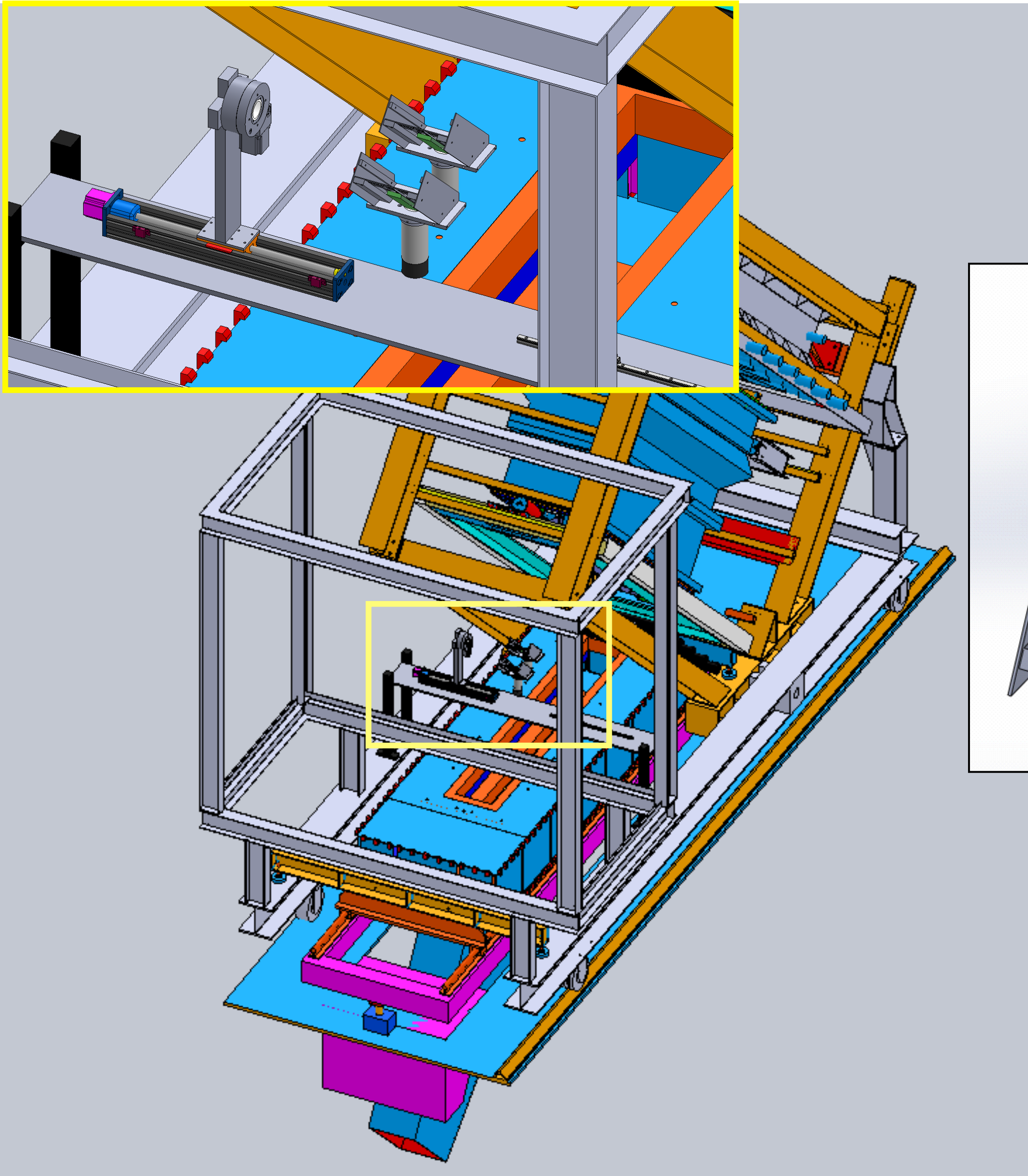
Q^2 acceptance, distribution

- From production target
- multiple measurements over run
- uncertainty mostly from angle



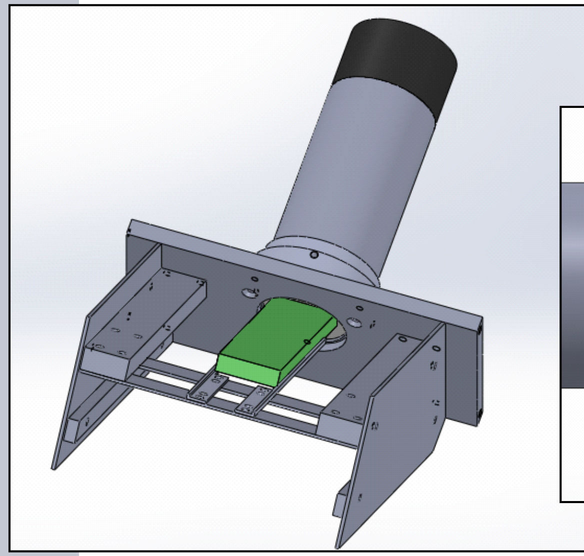
Known techniques. Requires watercell for each target position. GEMs will be installed to better control rate effects

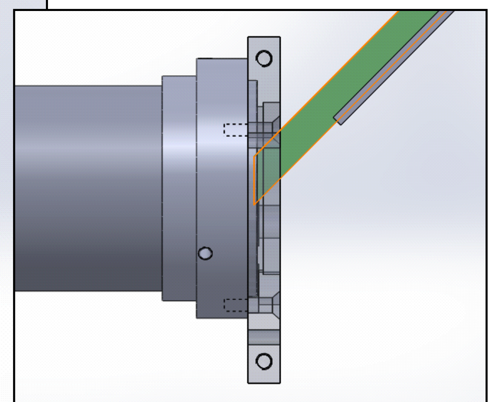
Integrating Detectors



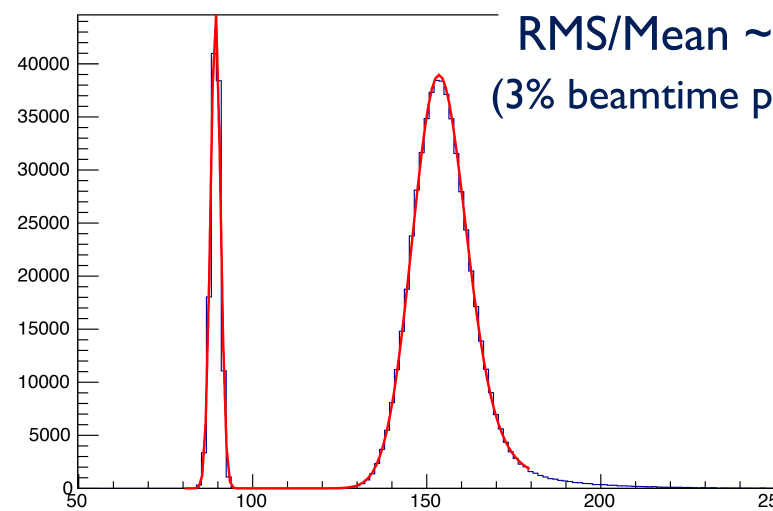
$$\sigma = \sigma_{stat}\sqrt{1+\sigma_{res}^2}$$

PREX-I: RMS/Mean ~ 36%
(12% beamtime penalty)





Mainz 2015 (90 deg)



RMS/Mean ~ 18%
(3% beamtime penalty)

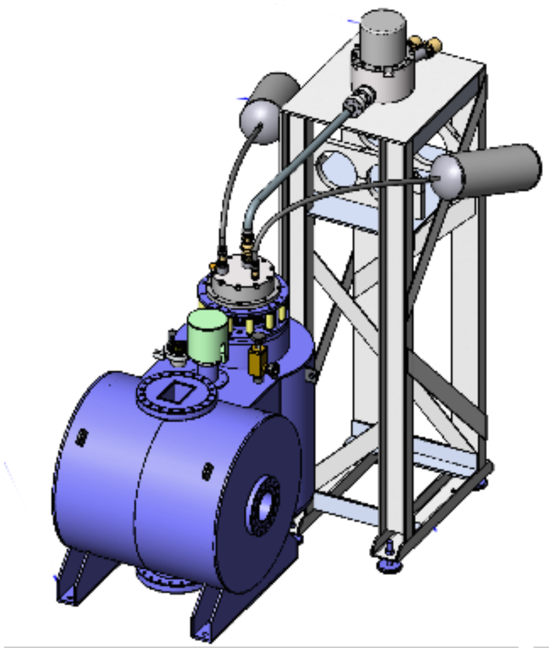
Concept ready. User design and assembly.

Polarimetry

On track for <1% in PREX-2 / CREX

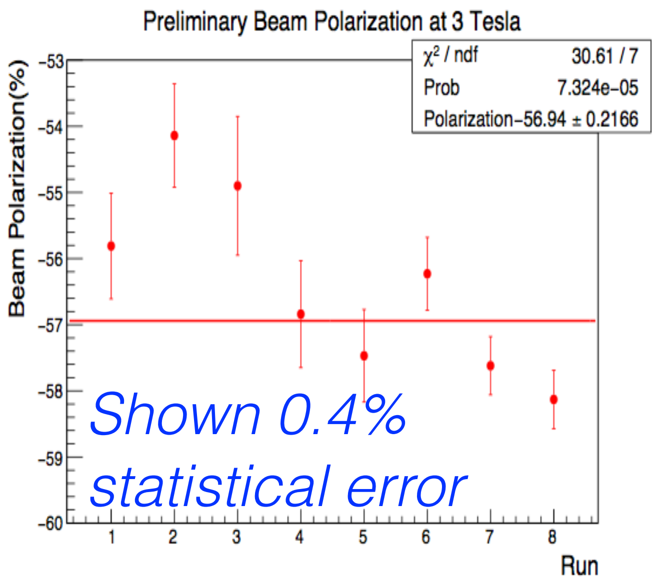
Moller

Iron Foil Target



- Beam operations in Fall 2016
- Rigid target rotator
- Test stand studies in 2017
- Test Kerr monitor (MOLLER pre-R&D)
- Prepare for installation in 2018

2015/16 operation



Compton

- **Green laser system**: successful for PREX-I
- Recent operation ok, requires some maintenance.
- Improved laser polarization measurement (0.2%) will improve error bar for CREX, installation planned summer ’16
- **Chicane:** successfully operated after upgrade
- **Integrating photon** analysis successful for PREX-I at ~0.5% precision
- GSO calorimeter, low energy photons for calibration
- highly linear base, diagnostics prepared at CMU
- **Electron Detector:** nice, but not required for CREX

Planning for commission and running

Planning has started for commissioning / running

As a start, we have the 2010 run plan:
https://prex.jlab.org/wiki/index.php/RunPlan

Critical systems have a defined chain of responsibility

System	JLab Staff Responsible	Collaboration Responsible
Target	Target Group	Silviu Covrig
Septum Magnet	Jack Segal	Juliette Mammei
Radiation Collimator	Robin Wines	Kent Paschke
Radiation Shielding	Robin Wines	Kent Paschke
Detectors	Jack Segal	Dustin McNulty
Data Acquisition	Robert Michaels	Raktiha Beminiwattha
Moller Polarimeter	Javier Gomez	Sasha Glamazdin, Jim Napolitano
Compton Polarimeter	Dave Gaskell	Gregg Franklin
Data Analysis	Robert Michaels	Kent Paschke, Seamus Riordan
Beamline	Doug Higinbotham	Krishna Kumar

Summary

Reference design is in place, and there has been progress towards a full design
(scattering chamber, target ladders, vacuum, radiation shielding, collimators)
Acquisition on scattering chamber has started

Techniques / devices are similar to PREX-I
(detectors, lead target, polarimetry, beam preparation and diagnostics, DAQ and analysis)

Collaboration support for all these components is in place

Next: Seamus, with a list of recommendations and specific responses